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BIBLIOGRAPHY OF STATISTICAL AND METEOROLOGICAL METHODOLOGY IN W--ETC(U)
SEP 76 M A HANSON, C L BACH, E A COOLEY N00014-76-C-0394
UNCLASSIFIED FSU-STATISTICS-M388 ONR-TR-110 NL

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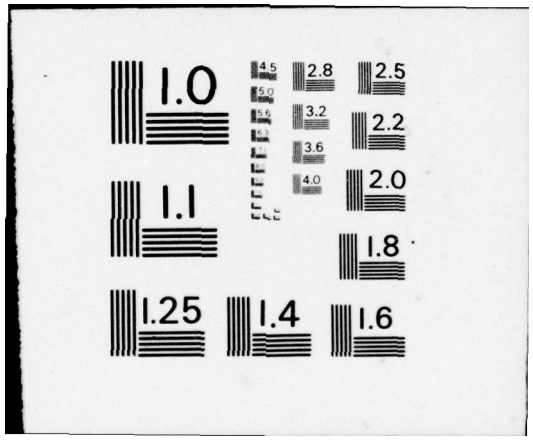
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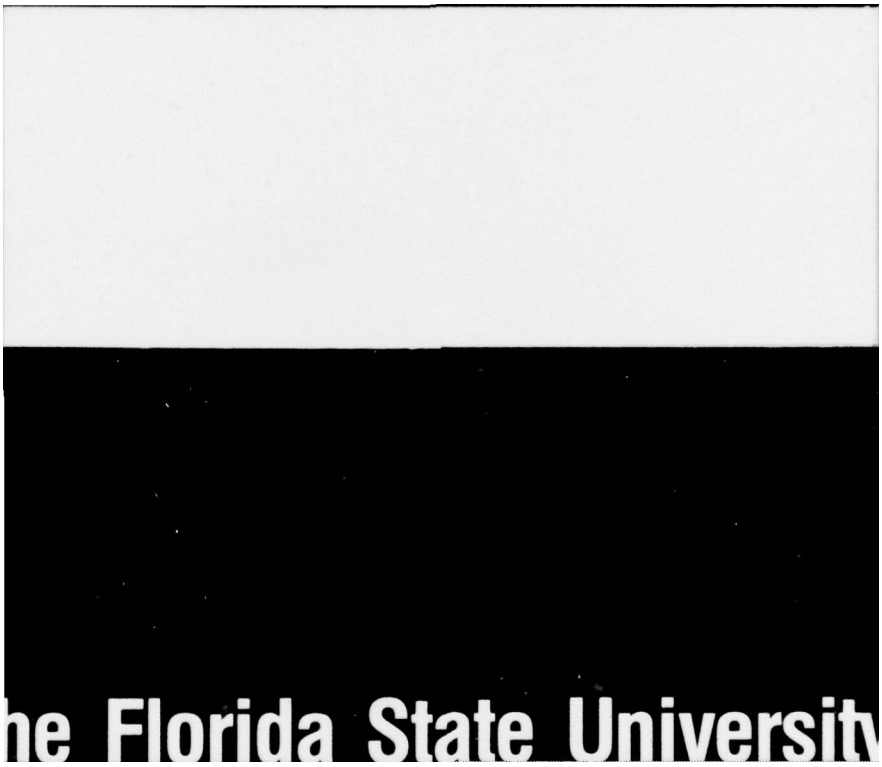
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6 BIBLIOGRAPHY OF STATISTICAL AND METEOROLOGICAL METHODOLOGY IN WEATHER MODIFICATION.

by

19 Morgan A. Hanson, Charles L. Bach[illegible] Edward A. Cooley

FSU Statistics Report No. M388
ONR Technical Report No. 110

18 19 TR-110

9 Technical rept., 14 FSU-Statistics-M388

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Bibliography of Statistical and Meteorological Methodology in Weather Modification

by

Morgan A. Hanson*, Charles L. Bach**, and Edward A. Cooley*.

Introduction

This collection of abstracts has been compiled within the Departments of Statistics and Meteorology at Florida State University for use in research in weather modification. Motivation for the bibliography arose in association with an ONR sponsored research contract in the design and analysis of weather modification experimentation under the direction of Ralph A. Bradley as Principal Investigator. It is envisaged that it will be of wide general use. The compilation has involved a systematic search of all available relevant meteorological and statistical journals, reports of symposia, and cross checks of references in the sources; and the use of such excellent reference material as provided by Neyman [1](1975), Neyman, Scott and Wells [2](1969), and Brier [3](1974).

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1. J. Neyman (1975). Problems of design and evaluation of rain making experiments, A Survey of Statistical Design and Linear Models, J. N. Srivastava, editor, North Holland Publishing Co., New York.

2. J. Neyman, E. L. Scott and M. A. Wells (1969), Statistics in Meteorology, Rev. Int. Statist. Inst. 37, 119-148.

3. G. W. Brier (1974) Design and Evaluation of Weather Modification Experiments, Weather and Climate Modification, W. N. Hess, editor, John Wiley and Sons, New York.

The bibliography extends through 1975. Any errors or omissions are the result of oversight or the unavailability of relevant material. It is intended to maintain an updating and correction of lacunae in the bibliography. Recommendations from interested users are invited. Supplements to this bibliography will be provided periodically.

One notable area of omission is the Russian literature which we do not have in English translation. One source reference is "Weather Modification in the Soviet Union, 1946-1966. A Selected Annotated Bibliography" by Nikolay T. Zikeev and George A. Doumani, Wash. D.C., Science and Technology Div., Reference Dept. Library of Congress (1967).

In abstracting the experimental literature we have concentrated on experimental design, type of seeding, meteorological conditions, response variables, and statistical techniques. In many instances this has proved to be surprisingly difficult because of the lack of key information in the publications. Another more general problem is the frequent absence or inadequate summary of data or description of statistical procedures which makes independent assessment of experimental results virtually impossible. Condensation of the enormous amounts of data obtained in a typical large scale weather modification experiment certainly presents a problem. It would seem very desirable that the meteorological and statistical societies establish a panel comprised of eminent meteorologists and statisticians to consider this and other matters pertinent to the standardization and uniformization of presentation of weather modification literature, and to make appropriate recommendations. Such a panel might consider wider issues: for example, the wide variety of statistical techniques that have been used in weather modification experiments, often in more or less similar circumstances, surely cannot be optimal. The desirability of establishing a data bank to permit further analysis of weather modification experiments by others interested should be considered. The bibliography is divided into two sections:

Section 1 - Abstracts of Experimental Literature.

Section 2 - Abstracts of Theoretical Literature and Discussion of Experiments.

The abstracts are arranged in alphabetical order within year of publication. The first two digits assigned to the numbering of the publication indicate the year of publication; a following numerical symbol refers to a direct experiment (Section 1); a following alphabetical symbol refers to theory or discussion (Section 2).

Each experiment has been coded as follows: (for example, 14-131-51-74 means that a crossover design was used with air generated silver iodide as the seeding agent. Rain gauges were used to measure the results, and the analysis was carried out by t-test).

Experimental Design

11 Two sample using control

12 Two sample using historical records

13 Two sample using estimate of normal rainfall from meteorological parameters

14 Crossover design

15 Single cloud seeding

16 Paired cloud seeding

17 Multiple cloud seeding, with randomly selected unseeded clouds

18 Random seeding of convective bands

19 Periodic seeding

20 Areal pattern recognition

21 Factorial design

22 None given.

Type of Seeding

Prefix 1 - air generated

Prefix 2 - ground generated

Prefix 3 - both air and ground generated

31 Silver iodide

32 Dry ice

33 Water

35 Sodium iodide

36 Sodium chloride

37 Lead aerosols

38 Burning vegetation; urban heat

39 Gasoline engine exhaust; industrial pollution

40 Morpholine, Ethylamine

41 Portland cement

42 Ammonium iodide

43 Ammonium nitrate

44 Urea

45 Phloroglucinol

46 Not specified

Response Variables

51 Rain gauges

52 Stream flows; reservoir runoff

53 Snow measurements

54 Ice counters

55 Particle or drop collectors; Spectrophotometers

56 Radar - cloud census

57 Radar - rainfall/hail/snow

58 Radiosonde

59 Visual; photographs; photogrammetry; crop damage

60 General weather data

61 Cloud texture

62 Hail indicators

Statistical Techniques

71 Regression

72 Correlation

73 z-test

74 t-test

75 Chi-square test

76 F-test

77 C(α) test

78 Single ratio test

79 Double ratio test; Composite ratio test

80 Median ratio test

81 Multivariate analysis

82 Analysis of variance

83 Analysis of covariance

84 Pattern analysis

85 Rank sum test

86 Sign test; Signed rank test

87 Squared rank sum test

88 Rank correlation

89 Kolmogorov-Smirnov test

90 None given.

SECTION 1
ABSTRACTS OF EXPERIMENTAL LITERATURE

1947
471
15-132-57/59-90
Kraus, E. B. and P. Squires, April, 1947, "Experiments on the Stimulation of Clouds to Produce Rain", Nature, 159, No. 4041, pp 489-491.

Experimental Design

Experiments were carried out in Australia, near Sydney, in 8 different clouds at time of writing. The objective was investigation of the artificial stimulation of rain. However this paper concerns itself with one particular test of 5 February, 1947.

Type of Seeding

Granulated CO_2 was dropped into top of a cloud.

Meteorological Conditions

Varied

Response Variables

Radar echoes, aircraft and farmer observations.

Statistical Techniques

None

Conclusions

Much further research is required before definite conclusions can be decided.

1949
491
15-132-59-90
Smith, E.J., March, 1949, "Experiments in Seeding Cumuliform Cloud Layers with Dry Ice", Australian Journal of Scientific Research, 2, No. 1, pp 78-91 plus 14 photographs.

Experimental Design

This paper describes five experiments in which granulated dry ice was dropped into layers of cumulus clouds of temperatures below freezing. The experiments were carried out over New South Wales in April, June and August, 1948.

Type of Seeding

CO_2 dropped into top of selected cloud.

Meteorological Conditions
Varied

Response Variables
Aircraft observations

Statistical Techniques
None

Conclusions
Seeding with dry ice caused a change from a cloud composed of water drops to one composed of ice crystals. There appeared to have been a good qualitative agreement between the density of the cloud and the amount of precipitation.

Comments
Fourteen photographs of effects of cloud seeding are given.

492
15-132-57/59-90
Squires, P. and E. J. Smith, June, 1949, "The Artificial Stimulation of Precipitation by Means of Dry Ice", Australian Journal of Scientific Research, 2, pp 232-245.

Experimental Design
In experiments carried out near Sydney, supercooled water clouds were seeded with ice crystals by dropping pellets of solid carbon dioxide into them. Up to August 25, 1948, 20 experiments were made.

Type of Seeding
60 pounds of CO_2 per cloud, at a rate of 10 to 30 pounds per mile.

Meteorological Conditions
Mostly cumulus clouds.

Response Variables
Aircraft observations, 10-cm aircraft radar and ground radar.

Statistical Techniques
None

Conclusions
Factors favoring precipitation are given plus a discussion of results.

1950
501
15-132-59/57-90
Fritch, Ronald, Jan., 1950, 'Artificial Nucleation of Clouds', The Meteorological Magazine, 79, No. 931, p 5-9.

Experimental Design

Six early cloud seeding experiments designed to either produce rain, control rain, or clear cloud during the year 1947-1949 were discussed. "Suitable" clouds were chosen and then randomly assigned to be seeded or not to be seeded. Changes in cloud shape, cloud size, and precipitation were observed.

Type of Seeding

Dry ice dropped from airplane varying in rate from 2 lb mi^{-1} to 10 lb mi^{-1}.

Meteorological Conditions

Varying cloud types.

Response Variables

Visual observations and radar.

Statistical Techniques

None

Conclusions

Not definite, though many observations had been made.

502
19-231-60-71/76
Langmuir, Irving, December, 1950, "A Seven-Day Periodicity in Weather in United States During April, 1950", BAMS, 31, pp 386-387.

Experimental Design

In December, 1949 a silver iodide ground-based generator has been operating in New Mexico by Project Cirrus on a schedule so planned as to introduce a 7-day periodicity.

Type of Seeding

Ground based silver-iodide generator.

Meteorological Conditions

Varied

Response Variables

Analysis of weather data using this periodicity has shown that significant effects can be detected at significant distances.

Statistical Techniques

Regression analysis, F-ratios, some discussion of periodic correlations.

Conclusions

A 4-step approach is given to evaluate the results of periodic seeding.

503
15-132-59-90
Orr, John L., D. Fraser, and K. G. Pettit, February, 1950, "Canadian Experiments on Artificially Inducing Precipitation", BAMS, 31, pp 56-59.

Experimental Design

A total of 57 trials from June 1948 to January 1949 were carried out. 30 were of random nature, the other 27 were selective. Trials were carried out in 4 different areas of Canada.

Type of Seeding

Dry ice inoculation was employed for all tests with rate of discharge varying from 2 to 10 lb/mi using 3/8" pellets.

Meteorological Conditions

Majority of clouds were summer time cumulus.

Response Variables

Mainly visual and qualitative.

Statistical Techniques

Not specified

Conclusions

Supercooled clouds were essential for the artificial induction of precipitation. Cumulus clouds had a higher percentage of successes than stratus. There was no evidence of lateral growth, and no evidence of critical amounts of dry ice for seeding.

Comments

8 tables of data and results are presented.

504
12-231/232-59-90
Vonnegut, Bernard, May, 1950, "Experiments with Silver Iodide Smoke in the Natural Atmosphere", BAMS, 31, pp 151-157.

Experimental Design

1) Ground released smoke generator; it was suggested that results were inconclusive and larger quantities should be used over larger areas so the result may be studied by statistical analysis of weather data.

2) Ag I from airplane; results were discussed of flights from Project Cirrus.

Type of Seeding

Ground smoke generators, dry ice, and silver-iodide.

Meteorological Conditions

Varied

Response Variables
Visual and photographs

Statistical Techniques
None

Conclusions
Success of silver-iodide seeding shows that further experimentation should give interesting and valuable results.

Comments
7 photographs given.

1952
521
17-133-59-90
Bowen, E. G., January, 1952, "A New Method of Stimulating Convective Clouds to Produce Rain and Hail", The Quarterly Journal of the Royal Meteorological Society, 78, No. 335, pp 37-45.

Experimental Design
Clouds were chosen so that a direct comparison could be made with nearby clouds. Upward velocity was highest, and there was no wind shear. Water drops were released in the base of clouds in the latter part of 1949 near Sydney, Australia on 11 occassions.

Type of Seeding
Drops were sprayed into cloud base at a rate of 30 gal./min. with a wide distribution of drop sizes having a median value of 50 μ.

Meteorological Conditions
Clouds meeting conditions above.

Response Variables
Aircraft observations

Statistical Techniques
None carried out other than collection of observations and comparison of such.

Conclusions
There was a high probability that the observed effects (clouds behaved differently; size of drops falling were of order of magnitude expected, there was consistent increase with time of thickness of cloud) were due to the spraying of water drops into cloud base.

522
12-331-51/57/59-90
Bowen, E.G., June, 1952, "Australian Experiments in Artificial Rainmaking", BAMS, 33, pp 244-246.

Experimental Design
Seeding was either by airplane or ground based generator. Only observations from airplanes over a circle of 50 miles radius from the ground base.

Type of Seeding
Airborne silver iodide and dry ice. Ground based silver iodide generator.

Meteorological Conditions
Varied

Response Variables
Visual observations, radar data, and regular raingauge networks.

Statistical Techniques
None

Conclusions
Quantitative and qualitative aspects were all doubtful as to whether the experiments affected total rainfall.

523
15-131/132/133-59/51-90
Bowen, E.G., July, 1952, "Australian Experiments on Artificial Stimulation of Rainfall", Weather, 7, No. 7, pp 204-209.

Experimental Design
Experiments were carried out for single cloud cells and for an area. However, experiments were designed to lead to an understanding of the physical processes which occur when different materials are injected into clouds.

Type of Seeding
Dry ice from 1947 to 1951. Silver iodide seeding. Water seeding.

Meteorological Conditions
Varied

Response Variables
Visual observations for single cells; downwind precipitation totals for area.

Statistical Techniques
None

Conclusions
Conditions necessary for rain to fall for the three type of seeding are given.

524
11-46-51-71
Brier, Glenn W. and Isadore Enger, May, 1952, "An Analysis of the Results of the 1951 Cloud Seeding Operations in Central Arizona", BAMS, 33, pp 208-210.

Experimental Design
This was a more complete analysis of the Arizona cloud seeding experiment. The experiment consisted of a control and target area with seeding for the Winter of 1951.

Type of Seeding
Not specified

Meteorological Conditions
Normal Winter in Arizona.

Response Variables
21 stations in target area, and 51 in control area of U.S. Weather Bureau raingages.

Statistical Techniques
Regression analysis, scatter diagram.

Conclusions
The results indicated that some caution should be used in interpreting these and similiar results.

525
11-46-51-71
Mac Cready, Paul B., Jr., February, 1952, "Results of Cloud Seeding in Central Arizona, Winter 1951", BAMS, 33, pp 48-52.

Experimental Design
Cloud seeding operations took place over a 10,000 square mile in Central Arizona during the first 4 months of the Winter of 1951. An adjacent unseeded area was used for correlation.

Type of Seeding
Not specified

Meteorological Conditions
Normal Winter conditions for Arizona.

Response Variables
Official U.S. Weather Bureau raingauges,however very few were used.

Statistical Techniques
Scatter diagrams, comparisons of ratios, and regression lines.

Conclusions
Precipitation increases suggest a large positive effect from cloud seeding.

531
11-132-52/59-71
Hall, Ferguson, T. J. Henderson, and Stuart A, Cundiff, March, 1953, "Cloud Seeding in the Sierra Near Bishop, California", BAMS, 34, pp 111-116.

Experimental Design

Cloud seeding was carried out over the High Sierra near Bishop, California during the Winters of 1948, 1949, 1950. Comparisons of the runoff from the seeded watershed are made with that from adjacent areas.

Type of Seeding

Dry ice from airplanes at a rate of 1 to 1.5 pounds per mile.

Meteorological Conditions

Varied except no seeding during storm passage.

Response Variables

Observations (visual) and comparisons of Bishop Creek flow with that of individual adjacent streams.

Statistical Techniques

Scatter Diagrams, multiple regression.

Conclusions

The average annual flow during the three-year period was augmented by 9%.

1954
561
12-231-51-71/72
Elliott, Robert D. and Robert F. Strickler, April, 1954, "Analysis of Results of a Group of Cloud Seeding Projects in Pacific Slope Watershed Areas", BAMS, 35, pp 171-179.

Experimental Design

The analysis presented was based upon a comparison of the seasonal precipitation falling in the target area to that falling in nearby control areas, all referred to historical comparisons. Three areas in the Pacific - slope watershed were chosen. (Sierra Nevada range in Calif., Southern Cascades of Oregon, and Bitterfoot Mountains of Idaho). The seeding was carried out from 1951-1953.

Type of Seeding

Gas type silver-iodide ground generators of about 10^{12} crystals s^{-1}.

Meteorological Conditions

Varied

Response Variables

Historical records stations were weighted accordingly to the Thiessen Polygon method.

Statistical Techniques
Scatter Diagrams, linear - regression line, correlations.

Conclusions
Shows cloud seeding effective in increasing precipitation averaged over a water-shed area.

1955
551
13-46-51-71
Buell, C. Eugene, January, 1955, "An Evaluation of the Results of Cloud Seeding in Western New Mexico and Southeastern Arizona During July and August, 1951 and 1952", BAMS, 36, pp 6-15.

Experimental Design
Three areas in Western New Mexico and Southeastern Arizona were studied during July and August of 1951 and 1952. Commercial efforts eliminated the use of a control area; so a reasonable estimate of the amounts of rainfall was obtained from certain meteorological parameters (eg. upper winds and radiosonde observations).

Type of Seeding
Not specified

Meteorological Conditions
Not specified

Response Variables
All three areas had a good density of rainfall reporting stations (map with locations given).

Statistical Techniques
Regression analysis, comparisons of tables.

Conclusions
From the data analyzed, if there is additional rainfall due to cloud seeding it can, at most, not exceed an amount of about 10%.

Comments
Relation of premise is based such that cloud seeding does not affect some upper air parameters.

552
13-46-51-72
Woodbridge, David D., January, 1955, "A Storm Analysis of the Tillamook Burn Cloud - Seeding Operation", BAMS, 36, pp 22-26.

Experimental Design

An area of 700 square miles in Oregon was used to evaluate cloud-seeding operations by the use of previously typed storm conditions.

Type of Seeding

Not specified

Meteorological Conditions

Summer storms

Response Variables

Normal precipitation recording stations for this area.

Statistical Techniques

Storm analysis correlation.

Conclusions

The storm analysis correlation technique could not be used to any advantage. However, it is proposed that this method would give results depending on the particular conditions.

1956
561
13-231-60-90
Oddie, B.C.V., March, 1956, "The Meteorological Office Experiments on Artificial Rainfall", Weather, 11, No. 3, pp 65-71.

Experimental Design

Generators were operated when a suitable cloud layer approached. Later, by a study of the winds, the seeded area and also two or more areas not seeded were identified. This approach was used in the Salisbury Plain in England.

Type of Seeding

Generator consisting of a brazier's lamp burning a solution of silver iodide in acetone.

Meteorological Conditions

Suitable belt of clouds.

Response Variables

None mentioned

Statistical Techniques

None mentioned

Conclusions

There were too many unknowns. It was suggested that the majority of the available resources be devoted to a study of the physics of the atmosphere, the mechanism of precipitation and the action of the seeding agents, in the hopes of eliminating the unknowns.

1958
581
11-131-51-78
Adderley, E. E. and S. Twomey, 1958, "An experiment on Artificial Stimulation of Precipitation in the Snowy Mountains Region of Australia", Tellus, 10, p 275-288.

Experimental Design

Seeding was confined to random periods, so that the intervening periods were available to provide control data. This report deals with the Snowy Mountain region of south-east Australia and describes the preliminary results from the first six months operation. This project was organized in June, 1955.

Type of Seeding

Airborne silver Iodide burner, which burned at the rate of 500 gm to 800 gm of silver iodide per hour.

Meteorological Conditions

Cumulus and stratocumulus clouds.

Response Variables

Isohyetal patterns were drawn from raingauge data. The authors concluded that precipitation estimated in this way furnished a better estimate of the true total than that given by individual gauges.

Statistical Techniques

Ratios of cumulative sums of precipitation in the target and control areas were considered.

Conclusions

The results indicate the ratios of target area to control area precipitation are greater during seeding periods; however there were not sufficient observations for results to be significant.

582
12- ? -52-71/73
Howell, Wallace E., Dec. 1958, 'A Reappraisal of an Early Cloud Seeding Evaluation', Journal of Meteorology, 15, p 562-563.

Experimental Design

During pasts of 1951 and 1952, cloud seeding was done for the purpose of increasing water storage in the Salmon and Stillwater reservoirs of the Niagara Mohawk Power Company in northwestern, New York State. Results were compared with historical records.

Type of Seeding

Not stated.

Meteorological Conditions

Varied

Response Variables
Runoff from 2 reservoirs in target area.

Statistical Techniques
t-test, z-test.

Conclusions
Cloud seeding significantly increased the runoff.

1960
601
11-231-51-76
Neyman, Jerzy, Elizabeth L. Scott, and Marija Vasilevskis, Oct., 1960, "Statistical Evaluation of the Santa Barbara Randomized Cloud - Seeding Experiment", Bulletin of the American Meteorological Society, 41, p 531-547.

Experimental Design
The experimental conditions of the Santa Barbara Project over the three years 1957 through 1959 were not uniform. The basic procedure was to seed January-April of each year. If a 12 hour unit was suitable for seeding, the randomized decision to seed was made.

Type of Seeding
Ground Generators (Ag I)

Response Variables
Raingauges

Statistical Techniques
F-test

Conclusions
The results are inconclusive. Difficulties are discussed. Recommendations for change in the design of the experiment are made.

1961
611
11-131-60-74/75/85/72
Adderley, E. E., Oct. 1961, "Non-Parametric Methods of Analysis Applied to Large-Scale Cloud-Seeding Experiments", Journal of Meteorology, 18, pp 692-694.

Experimental Design
Two climatologically similiar areas were chosen in Australia. Time was divided into roughly equal periods of 12 days, and in any one period the clouds in only one of the two areas were treated in random sequence.

Type of Seeding
Silver Iodide

Meteorological Conditions
Varied

Response Variables
Regular meteorological records

Statistical Techniques
1) t-test of regression line
2) alternative t-test (Moran)
3) X^2 test
4) Rank sum test
5) comparison of ratios

Conclusions
Parametric methods of statistical analysis depend upon assumptions whose validity in application to precipitation data may be in doubt. The confidence is therefore reduced. Non-parametric methods do not depend upon such assumptions, but they are usually less powerful. Therefore, the non-parametric tests are presented as additional rather than alternative tests.

1963
631
11-145-59-90
Braham, Roscoe R., Jr., Nov. 1963, 'Phloroglucinol Seeding of Undercooled Clouds', Journal of the Atmospheric Sciences, 20, p 563-568.

Experimental Design
19 releases from aircraft were made. 12 of these were phloroglucinol and 7 were dry ice which provided marker showers for navigational purposes. Comparisons were made between effects in the seeded region and outside the seeded region. The experiments were carried out on 18 and 19 December 1962, and 4 and 5 January 1963 in the off airways of northern Wisconsin and peninsula of northern Michigan.

Type of Seeding
Release rates varied from 42 to 2875 grams of phloroglucinol per mile of flight.

Meteorological Conditions
Thick altostratus or low stratus.

Response Variables
Formvar replicas, and co-pilot used gloved hand to check for ice particles outside window, visual observations.

Statistical Techniques
None mentioned

Conclusions
An organic material was found to be capable of initiating ice formation in field testing.

632
11-131/231-51-71/85
Siliceo, E. Perez, Ahumada A., and P. A. Mosiño, June 1963, "Twelve Years of Cloud Seeding in the Necaxa Watershed, Mexico", JAM, 2, pp 311-323.

Experimental Design
The Necaxa target area and its control area, 100 km to the ESE, were used. The seeding schedule was determined at random before the starting of operations each year. The seeding was carried out every year from 1949 to 1962 (except 1952).

Meteorological Conditions
Trade winds

Type of seeding
For the first five years airborne electric arc burners (25-50 gm hr) were used. From 1956, ground based burners were used.
1) An electric-arc type burning Ag I powder.
2) Butane-gas type burning a wick impregnated with 3 gm^{-1} of Ag I (consumption for both, 15-50 g of Ag I per day).

Response Variables
Rain was recorded daily at both target and control areas.

Statistical Techniques
Scatter diagrams, linear regression, rank tests for the difference between seeded and unseeded events.

Conclusions
Statistical methods show fair agreement in indicating a positive effect of seeding.

633
14-131-51/53-71/78
Smith, E. J., E. E. Adderley, and D. T. Walsh, June 1963, 'A Cloud-Seeding Experiment in the Snowy Mountains, Australia', JAM, 2, p 324-332.

Experimental Design
An area in the Snowy Mountains of Australia from 1955-1959 was divided into target, seeded, control, and neutral areas. Choice of seeding was done randomly from 15 March to 1 December.

Type of Seeding
Airborne silver-iodide burners each producing 10^{17} nuclei hr^{-1} at -17C.

Meteorological Conditions
Varied with season.

Response Variables
A total of 147 raingauges, 8 pluvio graphs, and 57 snow courses was used.

Statistical Techniques
Regression analysis, tests of ratios.

Conclusions
Over the five years, the ratio of the precipitation in the target area to that in the control area was higher in seeded than in unseeded areas.

Comments
Two full pages of data on seeded and unseeded periods are given.

634
11-131-51-85/71
Smith, E. J., E. E. Adderley, and F. D. Bethwaite, Oct. 1963, "A Cloud-Seeding Experiment in South Australia", JAM, 2, pp 565-568.

Experimental Design
Two areas were chosen in South Australia, each about 1000 square miles. Periods of cloud seeding were randomly chosen and seeded in the winter months of 1957, 1958, and 1959.

Type of Seeding
Airborne silver-iodide smoke generators.

Meteorological Conditions
Regular winter time climate.

Response Variables
Rainfall was measured by the Bureau of Meteorology, using 27 gauges in the North and 28 in the South. All were standard 8-inch, read at 0900 local time each day.

Statistical Techniques
Wilcoxon Mann-Whitney test, regression analysis was performed using a square-root normalizing transformation.

Conclusions
There was no evidence that cloud seeding influenced the mean precipitation.

1964
641
15-131-57/59-90
Malkus, Joanne S. and Robert H. Simpson, August 1964, "Modification Experiments on Tropical Cumulus Clouds," Science, 145, pp 541-548.

Experimental Design
Two aircraft penetrated each test cloud to record a "before" picture. Another aircraft followed and dropped its seeding bombs. The first two planes plus others made additional passes to record results.

Type of Seeding
Silver-iodide bombs

Meteorological Conditions
Clouds with tops naturally reaching 6 to 75 kilometers.

Response Variables
The temperature, liquid water content, and density of active freezing nuclei were measured by aircraft. Radar and visual observations were also used.

Statistical Techniques
No statistical techniques were used because of small sample size.

Conclusions
The authors believe that the results established beyond reasonable doubt the causal relationship between seeding and the observed explosive cloud growth which followed.

642
20-132-57-90
Takeda, K., Feb. 1964, "An Evidence of Effects of Dry-Ice Seeding on Artificial Precipitation", JAM, 3, pp 111.

Experimental Design
Clouds were seeded in a unique pattern distinct from any naturally occurring one and a corresponding pattern in the precipitation was sought. Six trials were conducted on 8 March 1963 in the vicinity of Hitoyoshi, Kyushu, Japan.

Type of Seeding
Dry ice pellets of about 1 cm^3 each were dropped at about 1 kg km^{-1} by airplane.

Meteorological Conditions
Temperature about - 8C

Response Variables
Radar

Statistical Techniques
None mentioned here (see Comments)

Conclusions
The resulting precipitation patterns show a correspondence to the seeding pattern.

Comments
The data and analysis are published in the "Journal of the Meteorological Society of Japan". A photograph of a radar raingauge shows their most striking case.

1965
651
11-131-51-74/71
Smith, E. J., E. E. Adderley and F. D. Bethwaithe, Aug. 1965, 'A Cloud-Seeding Experiment in New England, Australia', JAM, 4, pp 433-441.

Experimental Design
Two areas of approximately 2000 square miles were chosen. The choice of which area to seed was randomly chosen during the years 1958 to 1963. The areas are situated about 200 miles north of Sydney.

Meteorological Conditions
Varied according to time of season.

Type of Seeding
Airborne silver iodide smoke. The ice-nucleus output per burner was $3X10^{11}$ sec^{-1} active at -17C.

Response Variables
Standard 8-inch rain-gauges read at 0900 hrs, local time daily. 106 gauges in the north and 145 gauges in the south.

Statistical Techniques
t-tests and regression analysis

Conclusions
1) If the results of all six years are considered together, they suggest that seeding caused a small increase in mean rainfall.
2) Over the six year period there was a small difference between the north seeded area and south seeded area.

1966
661
14-131-51-85
Battan, Louis J., Oct. 1966, 'Silver-Iodide Seeding and Rainfall from Convective Clouds', JAM, 5, pp 669-683.

Experimental Design
A randomized scheme for seeding and not seeding was used. A target area of 15 by 20 miles in the Santa Catalina Mountains was chosen for tests in 1961, 1962, and 1964.

Type of Seeding
Airborne Ag I generator

Meteorological Conditions
A forecast that precipitable water between the ground and 400 mb should exceed 1.10 inch at 0500 MST was required.

Response Variables
29 recording raingauges

Statistical Techniques
Rank sum test

Conclusions
The data do not support hypothesis that rainfall was increased as a result of silver-iodide seeding.

Comments
Nine tables of rain or rainfall measurements are given.

662
15-131/135-55-85
Bethwaite, F. D., E. J. Smith, J. A. Warburton, and K. J. Heffernan, Aug. 1966, 'Effects of Seeding Isolated Cumulus Clouds with Silver Iodide', JAM, 5, pp 513-520.

Experimental Design
Isolated cumulus clouds with supercooled tops were seeded from an aircraft within 1800 km of Sydney in 1964. Either a large (20gm), small (0.2gm), or zero quanitity of silver iodide was used, with random choice of treatment.

Type of Seeding
Aircraft were used with two ice nucleus generators in which acetone solutions of Ag I and Na I were burnt.

Meteorological Conditions
A cloud was suitable for seeding if it met 11 specifications listed in the article. Major criteria were temperature, cloud base, cloud shape, isolation, and precipitation.

Response Variables

Measurement of rain through which the aircraft flew were made with an impactor fitted to the nose of the aircraft. No attempt was made to measure the rainfall at ground level.

Statistical Techniques

Rank sum test

Conclusions

Clouds with tops-10C or colder which were treated with the larger quantity of Ag I yielded significantly more rain than similiar untreated clouds. The reduced treatment gave insufficiently higher margin of precipitation to demonstrate statistical significance.

Comments

Detailed table of experiments presented.

663
11-131/135/231/235-51-71/83
Dennis, A. S. and D. F. Kriege, Oct. 1966, 'Results of Ten Years of Cloud Seeding in Santa Clara County, California', JAM, 5, pp 684-691.

Experimental Design

Target stations and control stations were selected in 1955. Ten seasons of commercial cloud seeding in Santa Clara County, California started in 1955 were evaluated.

Type of Seeding

Some from aircraft, but most from ground based generators burning a solution of Ag I and Na I in acetone in a propane flame. Typical consumption rate was 75 gm hr^{-1}.

Meteorological Conditions

Large-amplitude long-wave trough off West Coast.

Response Variables

25 target stations and 16 control stations for collecting precipitation data.

Statistical Techniques

Regression, analysis of covariance.

Conclusions

Comparison of rainfalls for the ten seeded years and the ten previously show a net increase in rainfall.

664
11-231-51- ?
Elliott, Robert D., Oct. 1966, "Effects of Seeding on the Energy of Systems", JAM, 5, pp 663-668.

Experimental Design

Details on the seeding and randomizing procedures have been published by Neyman et al (BAMS, 1960). Seeding was randomized in time. A primary target area (~450 mi^2) was chosen which included the Santa Ynez range in Santa Barbara County in California. The project was carried out through the years 1957-1960.

Type of Seeding

A network of 25 ground-based propane type Ag I smoke generators was employed to seed the whole county. The generators burned at a rate of 6 gm hr^{-1}.

Meteorological Conditions

Storms during 1957-1960.

Response Variables

Gauge density of 1 per 27 square miles in primary target area.

Statistical Techniques

A ranking test (no mention of kind), means and variances for each hour and then the averages over 35 non-seeded and 42 seeded cases were computed.

Conclusions

The preciptation in seeded periods was more than double that in non-seeded periods.

665
11-131-51-78
Godson, W. L., C. L. Crozier, and J. D. Holland, Aug. 1966, 'An Evaluation of Silver Iodide Cloud Seeding by Aircraft in Western Quebec, Canada, 1960-1963', JAM, 5, p 500-512. (Precipitation Physics Project)

Experimental Design

Two test areas 32 nautical miles square and separated by 32 nautical miles were chosen in Western Quebec province. A randomized cross-over technique was employed. The operating season was considered to be from 15 May to 15 September.

Type of Seeding

Airborne silver iodide smoke generator, producing about $2X10^{15}$ nuclei min^{-1} active at -17C.

Meteorological Conditions

Passage of synoptic-scale weather systems.

Response Variables

In 1959 - 30 raingauges, increased to 60 raingauges per area in 1960. Readings were taken at 0800 and 2000 local time.

Statistical Techniques

Ratios of seeded to unseeded areas were considered.

Conclusions

Analysis of the data of 45 storms seeded with silver iodide between 1960 and 1963 indicates a slight negative effect from seeding.

666

12-131/231-52/57-71/72/74

Henderson, Thomas J., Oct. 1966, 'A Ten Year Non-Randomized Cloud Seeding Program on the Kings River in California', JAM, 5, pp 697-702

Experimental Design

In 1954 a cloud seeding program designed to increase rainfall and snowpack was initiated over the watershed of the Kings River in Sierra Range of California. The project operated for ten years, continuously each season during the 7-month October-April seasons. The response was the flow of the Kings River.

Type of Seeding

A varying amount of Ag I from ground generators producing an average of 11.6 gm hr^{-1}. Airplanes were also used.

Meteorological Conditions

Varied (low pressure with trailing fronts, high pressure in British Columbia, etc.)

Response Variables

Flow of King's River. Radar was also used.

Statistical Techniques

Multiple regression analysis, correlation coefficients, t-test.

Conclusions

The analysis shows an apparent increase of 6% in the flow.

667

12-231-51-83/74

Howell, Wallace E. and Manuel E. Lopez, Oct. 1966, "Cloud Seeding in Southern Puerto Rico, April - July 1965", JAM, 5, pp 692-696.

Experimental Design

Since alleviation of drought was the primary objective randomization for scientific evaluation was forgone. Historical data for 25 control stations in target area was used for comparison.

Type of Seeding
23 Ag I smoke-generators capable of producing $3X10^{11}$ nuclei sec^{-1} active at -10C were used.

Meteorological Conditions
Northeast trade winds plus orographic effects

Response Variables
25 raingauges

Statistical Techniques
Covariance analysis, t-test

Conclusions
The analysis showed a 14% increase in average rainfall per rainy day.

Comments
Original control - target areas were discontinued when it was realized that there was poor association between the two due to other effects (i.e. rain at one area was due to one type of weather regime and rain in the other due to a different regime).

668
22-144-59-90
Knollenberg, Robert G., March, 1966, 'Urea as an Ice Nucleant for Supercooled Clouds', Journal of the Atmospheric Sciences, 23, p 197-201.

Experimental Design
Three tests using urea as a seeding agent were carried out on 15, 17 and 26 February 1965 in central and northern Wisconsin. No specific design was used.

Type of Seeding
Twenty pounds of urea were dropped in each of the field releases. The average rate of seeding was between 5 and 10 pounds per mile.

Meteorological Conditions
Supercooled clouds

Response Variables
Visual observations

Statistical Techniques
None

Conclusion
Results lead to the conclusion that urea is an effective seeding reagent for supercooled clouds.

669
15-131-59/57-90
Simpson, Joanne and R. H. Simpson, Aug. 1966, 'Stormfury Cumulus Experiments: Preliminary Results 1965', JAM, 5, p 521-525.

Experimental Design

Four or five instrumented aircraft penetrated cloud stacks at different levels. Randomized "seed" "no-seed" instructions were taken from a sealed envelope on the seeding aircraft. Twenty-two cases were studied on nine days, with fifteen seeded and seven controls, largely in matched pairs.

Type of Seeding

Sixteen Alecto units were released in a cloud. Each generator produced a little over 1 kg of Ag I.

Meteorological Conditions

Cumulus convective activity in the Carribbean Sea between July 28 and August 10 1965.

Response Variables

Photographic & radar records.

Statistical Techniques

None. There is some discussion of the probability of humidity differences in cloud columns.

Conclusions

Quantitative results show 2/3 of the properly seeded clouds underwent marked vertical growth while 6/7 of the controls did not.

6610
21-132-61-86/89
Vickers, William W. and James F. Church, Major, USAF, Feb. 1966, 'Investigation of Optimal Design for Supercooled Cloud Dispersal Equipment and Techniques', JAM, 5, p 105-118.

Experimental Design

A two level, two variable factorial design was used.

Type of Seeding

A prototype (cloudbuster) dry-ice pellet dispenser was used. The dispenser was capable of varying the output of CO_2 pellets, quantity of CO_2, and CO_2 pellet size. This machine was mounted in a C-130 aircraft.

Meteorological Conditions

A cloud deck was required.

Response Variables

Cloud texture break was measured by the Canadian photogrammetric grid technique (Twienkel, 1952). This technique was used to determine both the maximum area and width of the texture break area.

Statistical Techniques

Sign test, Kolmogorov-Smirnov Test.

Conclusions

Results showed that both the dry-ice seeding rate and pellet size, as well as cloud temperature, exerted a strong influence on cloud response.

1967
671
14-131-56-85
Battan, Louis J., April, 1967, "Silver-Iodide Seeding and Precipitation Initiation in Convective Clouds", JAM, 6, p 317-322.

Experimental Design

The experimental area was a mountain range having dimensions of about 15 by 20 miles in the Santa Catalina Mountains in southeastern Arizona. Pairs of days were taken together and one or the other was seeded on a random basis from 1957 to 1964.

Type of Seeding

2-4 hrs. by an airborne silver-iodide burner.

Meteorological Conditions

Experiments were carried out when convective shower activity was predicted.

Response Variables

A cloud-census technique was used; also radar data.

Statistical Techniques

The virtual absence of correlation among the pairs of days indicated the rank-sum test to be appropriate.

Conclusions

The results lead to the conclusion that airborne silver-iodide seeding may influence the precipitation initiation process in convective clouds.

672
11-236-51-80/85/74
Biswas, K. R., R. K. Kapoor, and K. K. Kanuga, Oct. 1967, "Cloud Seeding Experiment using Common Salt", JAM, 6, pp 914-923.

Experimental Design
Artificial stimulation of rain using warm cloud seeding was undertaken in three nearby climatologically similiar regions in northwest India. Randomized seed and no-seed days were used.

Type of Seeding
Ground based generators, 2500 gms of salt mixture/min.

Meteorological Conditions
Convective type activity

Response Variables
A close network of raingauges was used, read once daily at 0830 IST.

Statistical Techniques
1) the median ratio test
2) Wilcoxon-Mann-Whitney
3) t-test

Conclusions
A 21% increase in a season's total rainfall may be expected due to seeding.

673
14-131-51-72/78
Gabriel, K. R., Y. Avichai, and Raya Steinberg, April, 1967, "A Statistical Investigation of Persistence in the Israeli Artificial Rainfall Stimulation Experiment", JAM, 6, pp 323-325.

Experimental Design
This was a winter season (1961-1966) experiment with a randomized cross-over design using four areas aligned as follows: North, Buffer, Center, and South. Seeding was assigned randomly on each day either to the North or Center area. The Buffer and South areas served only as controls.

Type of Seeding
Ag I from aircraft

Meteorological Conditions
Rainy season

Response Variables
Daily rainfall reports from the Israeli Mateorological Service from its regular network of raingauge stations.

Statistical Techniques
Ratios, standard errors, and correlations are discussed.

Conclusions
The tests showed no evidence of persistence of effects of cloud seeding, either from day to day, or from season to season of the Israeli rainfall.

674
14-131-51-85
Gabriel, K. R., April, 1967, "Recent Results of the Israeli Artificial Rainfall Stimulation Experiment", JAM, 6, pp 437-438.

Experimental Design
On each day one of two experimental areas, North or Center in Israel, was randomly designated, and if suitable clouds were located, seeding was carried out. Evaluation was by a crossover comparison of amounts of precipitation in the two areas.

Type of Seeding
Ag I by airplane.

Meteorological Conditions
Rainy season

Response Variables
Daily rainfall reports from the Israeli Meteorological Service from its regular network of raingauge stations.

Statistical Techniques
Wilcoxon-Mann-Whitney test

Conclusions
Study of the data showed that seeding may have occasionally very strong effects and little or no effects on most days.

675
15-131-57/59-90
Ruskin, R. E., Feb. 1967, 'Measurements of Water-Ice Budget Changes at -5C in Ag I - Seeded Tropical Cumulus', JAM, 6, pp 72-81 [Project Stormfury].

Experimental Design
General procedures were the same as those of 1963 cumulus experiments (Malkus and Simpson, 1964; Simpson et al, 1965). The randomization methods used are reported by Simpson et al (1966). This paper discusses change in ice, water, and precipitation which were measured before and after seeding of 5 August, 1965 cloud.

Type of Seeding
"Alecto" pyrotechnic Ag I generators produced 180 Ag I nuclei per liter effective at $-5^{o}C$.

Meteorological Conditions
There was a line of cloud cells of which one cell was seeded.

Response Variables
Radar, photography, and dropsondes, plus assorted aircraft cloud measurement instrumentation.

Statistical Techniques
none mentioned

Conclusions
Measurements indicated the seeding of one cell of this particular tropical cumulus cloud by Ag I pyrotechnic smoke was effective in enhancing glaciation at -5C.

676
15-131-59-90
Simpson Joanne, Glenn W. Brier, and R. H. Simpson, Sept. 1967, "Stormfury Cumulus Seeding Experiment 1965: Statistical Analysis and Main Results", Journal of the Atmospheric Sciences, 24, pp 508-521.

Experimental Design
A randomized seeding experiment was carried out on 23 tropical oceanic cumulus clouds on nine days in the summer of 1965 as part of the joint Navy - ESSA Project Stormfury.

Type of Seeding
8-16 pyrotechnic silver iodide generators (Alecto units), each releasing about 1.2 kg of silver-iodide smoke.

Meteorological Conditions
Tropical cumulus

Response Variables
Aircraft, radar, and photogrammetry.

Statistical Techniques
Only the results of analysis were given.

Conclusions
The seeded clouds grew vertically an average of 1.6 km more than the control clouds, the difference being significant at the 0.01 level.

Comments
Summary results of Project Stormfury are presetned in tabular form.

1968
681
22-131-51-90
Adderley, E. E., 1968, "Rainfall Increases Down-Wind from Cloud Seeding Projects in Australia", Proceedings of the First National Conference on Weather Modifica- April 28-May 1, 1968, Albany, New York, pp 42-46.

Experimental Design
An examination of the rainfall downwind from two areas in Australia over which cloud seeding operations were carried out in 1966 and 1967.

Type of Seeding
Silver iodide smoke released from aircraft

Meteorological Conditions
Cumulus and strato-cumulus

Response Variables
Standard 8" raingauges read every 24 hours.

Statistical Techniques
None mentioned here

Conclusions
It appears that increases from artificial stimulation of precipitation extends considerably further down-wind than area at which operation is aimed.

682
22-131-51-75
Brown, Keith J. and Robert D. Elliott, 1968, "Large Scale Dynamic Effects of Cloud Seeding", Proceedings of the First National Conference on Weather Modification, April 28-May 1, 1968, Albany, New York, pp 16-25.

Experimental Design
This is an analysis of the spatial distribution of precipitation and hydrologic data in extended areas in,around, and downwind in four long term commercial cloud seeding programs in the Western U.S.

Type of Seeding
Ag I

Meteorological Conditions
Varied

Response Variables
Precipitation gauges and U.S. Weather Bureau cooperative observers.

Statistical Techniques
Chi-square test

Conclusions
The evidence gives strong support to the hypothesis that long term cloud seeding in Western U.S. has not only increased precipitation in the intended target area, but also in a large area approximately 100 miles downwind from the targets.

683
18-231-51-79/85/71
Elliott, Robert D. and John R. Thompson, Oct., 1968, "Santa Barbara Pyrotechnic Seeding Device Program: 1967-68 Winter Season Final Report", Naval Weapons Center Technical Publication 4645, China Lake, California.

Experimental Design

A randomized design was employed in Santa Barbara County, California. This project was a test of the effectiveness of ground - released pyrotechnics in enhancing precipitation during the period of January through April, 1968. The convective band was used as an observation unit. A sample of 11 seeded and 11 non-seeded bands was obtained.

Type of Seeding

The seeding was done by the LW-83 Ag I pyrotechnic at ground level. Each pyrotechic contained 76 grams of Ag I.

Meteorological Conditons

A control meteorologist examined his upwind telemetry and weather radar reports for the approach of the first convective band. When this band appeared, and was confirmed by tracking across the control area, the seeding technician was informed to ignite flares.

Response Variables

A network of 59 recording raingauges provided the primary basis for evaluation.

Statistical Techniques

1) Double Ratio
2) Rank-sum test
3) Test station - control average regressions were developed. (The t test was applied to find the significance.)

Conclusions

The results indicated doubling of precipitation in an area of over 500 square miles. There was some statistical significance attached to these results, but a larger sample would be desirable.

684
11-131-51/57-85/75
Flueck, John A., 1968, "A Statistical Analysis of Project Whitetops Precipitation Data", Proceedings of the First National Conference on Weather Modification, April 28-May 1, 1968, Albany, New York, pp 26-35.

Experimental Design

This paper presents a portion of the statistical analysis of the precipitation data of a five-year, 1960-64, randomized, summertime cloud seeding experiment conducted in Southern Missouri. The seeding was carried out over an area of 60 miles in radius, with a randomized scheme for seed and no-seed days.

Type of Seeding
Ag I

Meteorological Conditions
Varied, summertime.

Response Variables
Hourly precipitation data and ground radar

Statistical Techniques
Rank sum test, Chi-square test.

Conclusions
In all of the analyses the negative treatment effect was generally more strongly supported by comparison of the area of Ag I. Author inclined to more emphasis on the non-parametric results because of fewer assumptions.

685
14-231- ? -71/85
Grant, Lewis O., Charles F. Chappell and Paul W. Mielke, Jr., 1968, "The Recognition of Cloud Seeding Opportunity", Proceedings of the First National Conference on Weather Modification, April 28 - May 1, Albany, N.Y., pp 372-385.

Experimental Design
Randomized seeded and non-seeded samples were collected. Standard Weather Bureau stations to the southwest, west, and northwest were used for control stations near Climax, Colorado. The target area was the summit of Fremont Pass.

Type of Seeding
"Skyfire" needle-type ground generator.

Meteorological Conditions
Winter Orographic Cloud Systems

Response Variables
Not stated.

Statistical Techniques
Regression, rank sum test.

Conclusions
The results obtained are consistent with current orographic cloud seeding theory.

Comments
An elementary model for cold cloud precipitation efficiency is included.

686
14-131-51-83/85
Koscielski, Alexander and A. S. Dennis, 1968, "A Randomized Seeding Experiment in South Dakota", Proceedings of the First National Conference on Weather Modification, April 28-May 1, 1968, Albany, New York, pp 47-54.

Experimental Design
A randomized crossover design with target areas of roughly 700 square miles was used. The experiment was randomized by days with target area approximately 20 by 35 miles.

Type of Seeding
Primarily by an aircraft equipped with two Ag I generators and two racks carrying up to 14 pyrotechnic flares each.

Meteorological Conditions
Varied

Response Variables
Network of 100 raingauges read twice daily.

Statistical Techniques
Covariance analysis, rank sum test

Conclusions
On days with southwesterly flow, statistically significant increases of precipitation have been found in target areas. On days with northwesterly flow, the results are conflicting.

687
15-131-55-90
MacCready, Jr., P. B., and R. G. Baughman, Feb., 1968, "The Glaciation of an Ag I - Seeded Cumulus Cloud", JAM, 7, pp 132-135.

Experimental Design
The aim was to record from an airborne continuous cloud particle detector the distinct differences in particle characteristics between an unseeded and seeded cumulus cloud.

Type of Seeding
Cessna 180 aircraft were equipped with two Project Skyfire airborne Ag I generator units.

Meteorological Conditions
Cumulus clouds with relatively warm cloud temperatures (about - 5°C) were studied over western Montana on Aug. 30, 1966.

Response Variables

The MRI (Meteorology Research, Inc.) Continuous Particle Collector, an MRI Continuous Hydrometer Sampler, an open-ended Faraday Cage (which measured hydrometer charge) and a Hydrometic Box for collection of large graupel pellets were used.

Statistical Techniques

None carried out

Conclusions

Unseeded cloud consisted primarily of supercooled water droplets and the seeded cloud entirely of ice particles at the observed levels.

688
15-139-55-90

Morgan, Jr., Griffith M. and Paul A. Allee, April, 1968, "The Production of Potential Ice Nuclei by Gasoline Engines", JAM, 7, pp 241-246.

Experimental Design

Air samples containing potential ice nuclei were collected in aluminized mylar bags from a single - cylinder, 10-hp Kohler engine. Iodine vapor saturated air was added to activate the potential ice nuclei in individual clouds.

Meteorological Conditions

Varied

Type of Seeding

Gasoline engine exhaust

Response Variables

Gardner small-particle counter.

Statistical Techniques

Scatter Diagrams are given, with some approximate calculations of the effect of automobiles in a city (Denver).

Conclusions

Quantitative sample calculations showed that large enough numbers of potential ice nuclei are produced by the routine burning of gasoline to be useful in cloud and weather modification.

689
11-236-51/57-85/74

Murty, Bh. V. Ramana and K. R. Biswas, 1968, "Weather Modification in India", Paper presented in the Proceedings of the First National Conference on Weather Modification, April 28 - May 1, Albany, New York, pp 71-80.

Experimental Design

Control and target sectors were fixed on the basis of winds from the surface up to 2.5 km. Experiments were carried out in plains (Delhi, Agra, and Jaipur) and also in mountain ranges (Munnar). The areas ranged from 175 to 490 square miles.

Type of Seeding

Spraying from ground dilute salt solution of known concentration.

Meteorological Conditions

Convective clouds.

Response Variables

A raingauge network that varied from 1 to 10 square miles to 1 per 115 square miles. Also some radar.

Statistical Techniques

Rank-sum, t-test.

Conclusions

Results have indicated a positive trend. The findings have suggested that about 40% increase in precipitation is possible by cloud seeding from ground.

6810
14-131/231-51-71

Spar, Jerome, 1968, "Design Study For a Cloud Seeding Experiment in the Northeastern United States", in Proceedings of the First National Conference on Weather Modification, April 28-May), Albany, New York, pp 55-58.

Experimental Design

This is a design for a randomized, two-area, cross-over design using aircraft seeding. This is supplemented by a one-area randomized ground level seeding experiment and a non-randomized ground level seeding operation.

Type of Seeding

Silver Iodide generators of Project Skyfire type.

Meteorological Conditions

The mean relative humidity should be greater than 70% or there should be precipitation in the region.

Response Variables

Rain gauges

Statistical Techniques

Regression analysis

Conclusions

The actual conduct of the experiment will be arranged by ESSA following completion of the design study.

6811
22-131/132-57-90
Takeda, K., 1968, "Some Recent Results of Weather Modification Activities in Japan", Proceedings of the First National Conference on Weather Modification, April 28-May 1, 1968, Albany, New York, pp 8-15.

Experimental Design
The design is not specifically stated. Two experiments are presented and a third is outlined.

Type of Seeding
Dry ice pellets or silver iodide smoke from an aircraft.

Meteorological Conditions
Varied

Response Variables
3 cm radar

Statistical Techniques
None

Conclusions
The author feels that artificial precipitation depends largely on weather condition and natural precipitation. He feels that there do exist certain adequate weather conditions when there will not be natural precipitation but there can be artificial precipitation; but in fact such conditions occur very rarely.

6812
11-238-51-90
Warner, J., April 1968, 'A Reduction in Rainfall Associated with Smoke from Sugar-Cane Fires - An Inadvertent Weather Modification', JAM, 7, p 247-251.

Experimental Design
Two areas were chosen, one lying in the direct trajectory of smoke from cane fires and one that did not. Daily records were examined to insure that the control area was not exposed to smoke from the cane fires. Comparison was made with synoptic measurements for the previous sixty years.

Type of Seeding
Burning of sugar cane.

Meteorological Conditions
Winds were selected to insure that the control area was clear of cane smoke.

Response Variables
Rain gauges.

Statistical Techniques

Scatter diagrams are given.

Conclusions

The reduction downwind is consistent with the hypothesis that through their activity as condensation nuclei the smoke particles result in great increases in concentration and consequent reduction in the size of cloud droplets, thereby hindering the coalescence process of rain.

1969
691
18-231-51-79/85
Elliott, Robert D. and John R. Thompson, Oct., 1969, "Santa Barbara Device Test Program: 1967-68 and 1968-69 Seasons", Naval Weapons Center Technical Publication 4816, China Lake, California.

Experimental Design

A randomized design was employed in Santa Barbara County, California. This project was a test of the effectiveness of ground released pyrotechnics in enhancing precipitation during the winter seasons. There were 30 seeded convective bands, and 33 not seeded.

Type of Seeding

The seeding was done by the LW-83 Ag I pyrotechnic at ground level. Ag I output was 399 grams/unit.

Meteorological Conditions

1) The wind flow must be such that with the existing thermal structure, the effects of the seeding will fall mainly in the target area.

2) The air mass structure should be such as to ensure mixing from the seeding site to the -4°C level or higher.

Response Variables

A network of 62 raingauges were employed for the analysis.

Statistical Techniques

1) Double ratio
2) Composite ratio
3) Rank-sum test.

Conclusions

1) This seeding mode can be effectively employed provided there is suitable upwind telemetered raingauge information to define bands.

2) The seeding device used in the mode employed was highly effective in increasing downwind precipitation. The seeded precipitation was double that of non-seeded precipitation.

3) There is an inhibiting effect of seeding efficiency in the colder storms.

692
11-231-51-77
Neiburger, M. and Ho-Chik Chin, April, 1969, "The Meteorological Factors Associated with the Precipitation Effects of the Swiss Hail Suppression Project", Journal of Applied Meteorology, 8, p 264-273.

Experimental Design

A randomized process was used for seeding or non-seeding after a hail-storm was predicted. This project was carried out during 1957-1963 to suppress hail in the Southern Alps.

Type of Seeding

Ground based Silver-Iodide Generators (23 total).

Meteorological Conditions

Possibility of a hail storm.

Response Variables

24 raingauges.

Statistical Techniques

C(α) test

Conclusions

While the results from the stand point of hail suppression were negative, there appears to have been a definite overall effect in increased precipitation on days with seeding.

693
14-131-51-77
Neyman, Jerzy, Elizabeth Scott, and Jerome A. Smith, 1969, "Areal Spread of the Effect of Cloud Seeding at the Whitetop Experiment", Science, 163, p 1445-1449.

Experimental Design

Project Whitetop was carried out during 1960-1964. Data was collected for 24 hour periods for six concentric regions up to 180 miles from the center of the target. Randomized seeding was used.

Type of Seeding

Silver Iodide

Statistical Techniques

Optimal C(α)

Conclusions

When a 5-year experiment, expected to produce a 5 to 10 percent increase, shows a 20 percent decrease in rainfall, the relevant technology does not appear reliable enough for practical use.

Also mentioned are seeding effects up to 150 miles, which makes data from cross-over designs with buffers less than 40 miles unuseable.

694
14-131-51-71/83/76
Mooney, Margaret L. and George W. Lunn, Feb. 1969, "The area of Maximum Effect Resulting from the Lake Almanor Randomized Cloud Seeding Experiment", JAM, 8, pp 68-74.

Experimental Design
Target and control areas were chosen according to wind flow. The target area was further split into two approximately equal parts, with random choice of which target area to seed. Thus, when wind direction was southerly, a crossover design was used; when westerly, one-half was used on controls.

Type of Seeding
Six Ag I burners were used with capacity to produce 25 g hr^{-1} of Ag I.

Meteorological Conditions
Wind conditions dictated the experimental design.

Response Variables
Continuous precipitation measurements by U.S. Weather Bureau weighing type gauges were used at 49 locations.

Statistical Techniques
Regression, covariance analysis, and F test were used.

Conclusions
Positive effects found in the cold-westerly category are in general agreement with the hypothesis that Ag I seeding stimulates only the ice-crystal mechanism of the natural precipitation processes, and has no effect on the warm temperature coalescence mechanism.

695
17-131-59/57-74/72
Weinstein, A. I. and P. B. Mac Cready, Jr., Dec. 1969, "An Isolated Cumulus Cloud Modification Project", JAM, 8, pp 936-947.

Experimental Design
A randomized seeding experiment was conducted in Flagstaff, Arizona, in July and August of 1967. 21 clouds were studied, 10 seeded and 11 not seeded on 11 days. For 9 days paired seed and no-seed clouds were studied.

Type of Seeding
Airborne seeding with Ag I acetone burners was used.

Meteorological Conditions
The decisions on which clouds to use were made by a systematic series of 6 cloud calculations, performed on each morning's sounding.

Response Variables

Ground and aircraft observers including 3-cm radar data were used.

Statistical Techniques

Student - t tests were used and correlation coefficients calculated.

Conclusions

For the 21 test clouds there were increases in radar tops, precipitation, and duration. On every one of the 9 paired days, the seeded clouds showed increased height, rainfall and duration.

1970
701
14-331-59-74/85

Bartin C., H. Isaka, and G. Soulage, 1970, "Statistical Studies on French Operations for Hail Suppression", Second National Conference on Weather Modification, April 6-9, Santa Barbara, California, pp 134-139.

Experimental Design

Two operations were carried out in the southwest of France to prevent hail. One area was 70,000 km^2, the other about 9,000 km^2. A target and control area was established in each.

Type of Seeding

Ag I ground and air.

Meteorological Conditions

Varied

Response Variables

Hail damage to crops.

Statistical Techniques

t-test, rank sum test

Conclusions

The results show that it is impossible to assert the validity of hail prevention operations only through statistical control.

702
11-131/135-57-90

Dennis, A. S., A. Koscielski, J. H. Boardman, and G. A. D. Peterson, 1970, "Use of Moving Target Areas and On-Line Computer In Experimental Seeding of Convective Clouds", Second National Conference on Weather Modification, April 6-9, Santa Barbara, California, pp 190-192.

Experimental Design

The project utilized movable target areas defined by a grid centered on a radar site. During the summer of 1969 a three way randomized project was set up. The three treatments were (1) no seed, (2) silver iodide seed and (3) salt seed.

Type of Seeding

Silver iodide was released by burning flares each containing 120 gm Ag I. Salt seeding was performed by releasing 50 Kg of finely ground salt.

Meteorological Conditions

Summer storm conditions (mainly cumulus clouds)

Response Variables

3.2 cm radar

Statistical Techniques

None presented

Conclusions

The idea of movable targets proved feasible.

703
18-131-51-79/85
Elliott, Robert D. and John R. Thompson, 1970, "Santa Barbara Pyrotechnic Seeding Device Test Program", Second National Conference on Weather Modification, April 6-9, Santa Barbara, California, pp 76-79.

Experimental Design

Seeding was confined to convection bands occuring in the winter storms that passed through Santa Barbara County.

Type of Seeding

Silver iodide.

Meteorological Conditions

Winter storms

Response Variables

Recording raingauges

Statistical Techniques

Double Ratio, Rank-sum Test.

Conclusions

Band seeding was effective in increasing precipitation and the convective band was a feasible unit of observationa.

704
15-131-57/59-90
Henderson, Thomas J., 1970, "Results From a Two-Year Operational Hail Suppression Program in Kenya, East Africa", Second National Conference on Weather Modification, April 6-9, Santa Barbara, California, pp 140-144.

Experimental Design
This is a report of a hail suppression program from October 1, 1967 through September 30, 1969 in the Kericho area of Kenya. Operations were conducted over a 800 square miles area. As many individual cumulus cells were treated as possible. (860 cases).

Type of Seeding
Ag I seeding from aircraft at cloud base.

Meteorological Conditions
Cumulus clouds

Response Variables
Radar (3.2 cm Atmos IV Weather Radar System).

Statistical Techniques
Results to be presented later.

Conclusions
Results of average tea loss due to hail suggested a 58.5% reduction in hail.

705
12-239-55-74/71
Hobbs, Peter V., L. F. Radke, and S. E. Shumway, Jan. 1970, "Cloud Condensation Nuclei from Industrial Sources and Their Apparent Influence on Precipitation in Washington State", Journal of the Atmospheric Science, 27, pp 81-89.

Experimental Design
Measurements of the concentrations of cloud condensation nuclei (CCN) show certain industries (eg. pulp and paper mills) are prolific sources of CCN. Downwind precipitation and streamflow records and observations were made in Washington to see if CCN do in fact affect the precipitation and stream flow observations were compared with records in Washington for the periods 1929-1946 and 1947-1966.

Type of Seeding
CCN produced by paper and pulp mills.

Meteorological Conditions
Varied

Response Variables
Observations of CCN.

Statistical Techniques
Scatter Diagrams, t-tests, and regression analysis.

Conclusions
Comparison of the two time periods show that a number of areas have had a mean annual precipitation during the second period greater than the first as a consequence of the increased CCN emitted into the atmosphere.

706
11-231-51-85-87
Mielke, Paul W., Lewis O. Grant, and Charles F. Chappell, Feb. 1970, "Elevation and Spatial Variational Effects of Wintertime Orographic Cloud Seeding," Journal of Applied Meteorology, 9, pp 476-488.

Experimental Design
Randomization was applied using a 24-hour sampling unit. The effects were studied in an area in the central Colorado mountains during the winters of 1960-1965. Only target area data was used.

Type of Seeding
Modified "Skyfire" needletype ground generators.

Meteorological Conditions
At least 0.01 inch of precipitation was forecast during a sampling unit.

Response Variables
65 precipitation stations.

Statistical Techniques
Rank sum test, squared rank sum test.

Conclusions
The average daily precipitation for all seeded days was somewhat greater than the average daily precipitation for all non-seeded days.

707
22-237-54/55-90
Parungo, Farn P. and J. Owen Rhea, June, 1970, 'Lead Measurements in Urban Air As It Relates to Weather Modification', JAM, 9, pp 468-475.

Experimental Design

Airborne and ground measurements of precipitation using three independent measurement techniques plus a special rainfall sampling network were made in Denver urban air. The objective was to study the behavior of lead aerosols as latent ice nuclei.

Type of Seeding

The main source of lead in urban air is the burning of antiknock additives in automotive fuel.

Meteorological Conditions

a) Temperature inversion
b) Unstable atmosphere

Response Variables

1) An NCAR ice counter
2) an atomic absorption spectrophotometer
3) Tufts' spot test for obtaining lead particle concentration and size distribution.

Statistical Techniques

none mentioned

Conclusions

Results showed a good qualitative agreement among three types of measurment of lead; lead content was an order higher in magnitude when used as a seeding agent, and 10-300 lead particles liter^{-1} which could be converted to ice nuclei at 9,000 ft.

108

II-131/231-53-87

Chen, J. Owen and L. G. Davis, 1970, "Statistical Results of the Park Range Winter Orographic Cloud Seeding Experiment", Second National Conference on Weather Modification, April 6-9, 1970, Santa Barbara, California, pp 70-75.

Experimental Design

Randomization was employed for 6 hr blocks during 1968-69 near Steamboat Springs in northwestern Colorado. Each six-hour block was subdivided into two three-hour blocks.

Type of Seeding

Silver iodide by both ground and air. The ratio respectively are 240 gm per hour and 450 gm per hour.

Meteorological Conditions

Winter orographic Conditions

Response Variables
1) optical snow rate sensor
2) snow samples collected on plastic sheets
3) snow crystal sensors

Statistical Techniques
Squared-rank-sum-test

Conclusions
The data showed that seeding increased the snow silver content by a factor of two; and produced large (>100%) increases of precipitation.

709
12-131-51-86
Schickedanz, Paul T. and F. A. Huff, 1970, "An Evaluation of Downwind Seeding Effects from the Whitetop Experiment", Second National Conference on Weather Modifications, April 6-9, Santa Barbara, California, pp 180-185.

Experimental Design
This is a further investigation of the possibility of downwind seeding effects through the use of data and analyses not previously employed for the Whitetop seeding project in Missouri. A circular sampling area with a 300 mi radius was used. Average monthly rainfall totals for the seeding period (1960-1964) and the previous 5-year period (1955-1959) were compared.

Response Variables
Dense raingauge networks were used at 175 and 290 miles downwind; otherwise the gauge density was 1 per 300 mi^2.

Statistical Techniques
Signed rank test

Conclusions
The overall conclusion is that the evidence for downwind effects from the Whitetop experiment is very weak.

7010
11-131-62-85/71
Schleusener, R. A., Alexander Koscielski, A. S. Dennis, and M. R. Schock, 1970, "Hail Experience on Eight Project Seasons of Cloud Seeding with Silver Iodide in the Nothern Great Plains", Second National Conference on Weather Modification, April 6-9, 1970, Santa Barbara, California, pp 145-149.

Experimental Design

Hail impact energies were measured on three observational networks in the northern Great Plains during eight summers between 1966 and 1969 inclusive. 48 storms were studied, 30 were unseeded and 18 were seeded.

Type of Seeding

The main type of seeding was the release of 0.5 to 1.0 kg hr^{-1} of silver iodide from aircraft at cloud base.

Meteorological Conditions

Summer Great Plains storms.

Response Variables

Hail indicators (number depends on area)

Statistical Techniques

Rank sum test, regression analysis.

Conclusions

Reduction of hail energies by 70% by silver iodide seeding is indicated.

7011
11-131-51-71
Siliceo, Emilio Perez, 1970, "19 Years of Cloud Seeding Operations in the Necaxa, Puebla and Lerma, Mexico, Watersheds, From the Periods 1949-1951 Plus 1953-1968" Second National Conference on Weather Modification, April 6-9, Santa Barbara, California, pp 87-90.

Experimental Design

The Necaxa watershed was used as a target area with a control area upwind.

Type of Seeding

Ag I

Response Variables

Rainfall totals

Meteorological Conditions

Varied

Statistical Techniques

Regression Analysis

Conclusions

Tentative physical results are given.

7012
17-131-57-90
Simpson, Joanne, William L. Woodley, Howard A. Friedman, Thomas W. Slusher, R. S. Scheffee, and Roger L. Steele, (Feb. 1970) "An Airborne Pyrotechnic Cloud Seeding System and Its Use." JAM, 9, pp 109-122.

Experimental Design

The purpose of the experiment was to study the induced dynamic and physical changes in seeded clouds and to compare these with unseeded control clouds, both chosen on a randomized basis. The experiment was conducted in Florida in May, 1968.

Type of Seeding

Pyrotechnic flares producing 50 gm of Ag I smoke each.

Meteorological Conditions

The size of subject clouds was about 1.5 - 3.0 km in tower diameter, 6.8 km in height, with cloud bases approximately 500 - 1000 m and freezing level approximately 4 km.

Response Variables

Airplane measurements and ground radar were used to infer rainfall from cloud base (discussed in subsequent paper).

Statistical Techniques

Particulars were not given.

Conclusions

Of the 14 seeded clouds, 13 grew explosively. Large increases in rainfall were found from seeded clouds.

Comments

A table is given of Supercooled cumulus seeding experiments using aircraft. (1951 - 1968).

7013
11-131-51-90
Smith, E.J., October, 1970, "Effects of Cloud - Top Temperature on the Results of Cloud Seeding with Silver Iodide in Australia", JAM, 9, pp 800-804.

Experimental Design

Three areas were tested. (New England, Warragamba (Near Sydney), and South Australia). In each of the three there was two specified areas, designated 'north' and 'south' of 1,000- 3,000 mi^2. During the time periods, clouds over one or the other areas were seeded with silver-iodide smoke released from aircraft. Choice of area was random.

Type of Seeding

Ag I smoke from airplanes

Meteorological Conditions

Clouds were deep, durable and compact. Tops contained supercooled water colder than -5°C, the threshold temperature of nucleation of Ag I.

Response Variables

Networks of 30-150 raingages per area. The gauges were read at 0900 hours local time the next day.

Statistical Techniques

Tables and graphs are presented, but no mention of statistical techniques.

Conclusions

It appeared that seeding cumuliform and mixed clouds w/ tops colder than -10C to -15C increased the rainfall, while seeding clouds with warmer tops reduced it.

7014
16-131-59/57-79
Williams, M. C. and D. E. Lehrman, 1970, "Sierra Cumulus" Second National Conference on Weather Modification, April 6-9, Santa Barbara, California, pp 81-86.

Experimental Design

There was random seeding of one of a pair of similar non-precipitating clouds. Seeding was carried out during the summer season in the Sierra Nevada from Central California south to the Tehachapi Mountains. 47 test cases were developed.

Type of Seeding

Aircraft silver iodide.

Meteorological Conditions

Summer time cumulus cloud pairs.

Response Variables

Visual and photographic observations, plus radar measurements.

Statistical Techniques

Chi-square

Conclusions

Results indicated that seeding was responsible for producing precipitation from non-precipitating clouds with a significance level of 0.999.

Comments

This was one phase of a four phase project for use by a water resource group.

7015
11/12-138-51-88
Woodcock, A.H. and Richard H. Jones, August, 1970, "Rainfall Trends in Hawaii", JAM, 9, pp 690-696.

Experimental Design

Two physically similiar leeward coastal areas in Hawaii were selected for comparison; One was downwind from a major cane-growing area and the other not. Results were compared with historical data.

Type of Seeding

Burning sugarcane produces ~ $5x10^{12}$ cloud nuclei per gram of leaf.

Meteorological Conditions

Persistent northeast trade winds

Response Variables

Five criteria for selecting raingages were used.

Statistical Techniques

Rank correlation of annual rainfall with time was carried out. Tests for trends within entire region were made.

Conclusion

It was concluded that factors other than cane-fire smoke are probably involved in any rainfall trends which may exist.

7016
17-131-57-73/74/85
Woodley, William L., (April, 1970), "Precipitation Results from a Pyrotechnic Cumulus Seeding Experiment" JAM, 9, pp 242-257.

Experimental Design

19 clouds here studied, 14 seeded and 5 control using randomized seeding instructions. The experiment was carried out in South Florida during May, 1968.

Type of Seeding

Airborne Ag I pyrotechnics were used with each of 14 clouds receiving about 1 kg of Ag I smoke.

Meteorological Conditions

1) hard appearance with tops between 19,000 - 26,000 ft.
2) minimum supercooled water content 1 gm m^{-3}.
3) cloud still vigorous after first penetration of aircraft
4) Isolation from other convective activity

Response Variables

A modified UM/10 radar was used to collect precipitation rate data on film.

Statistical Techniques
a) pooled student - t with variances assumed equal
b) Normal Scores test
c) Wilcoxon - Mann - Whitney test

Conclusions
Analysis of observations showed that Ag I pyrotechnic seeding of supercooled Florida cumuli induced cloud growth. Three different two tailed tests, strongly supported the hypothesis that invigoration of cloud dynamics increases rainfall.

7017
15-131-57-74/85
Woodley, William L., Oct. 1970, "Rainfall Enhancement by Dynamic Cloud Modification," Science, 170, pp 127-132.

Experimental Design
Individual cumulus clouds over or near the Florida peninsula were seeded in May 1968. Seeding was done randomly. 19 experimental clouds were studied: 14 seeded clouds and 5 control clouds. Seeding was done by dropping twenty flares in a cloud.

Type of Seeding
Silver-iodide, 50-gram flares

Meteorological Conditions
Growing supercooled cumulus

Response Variables
Aircraft and ground radar

Statistical Techniques
Rank sum test, t-test

Conclusions
The above dynamic approach is effective in inducing growth and increasing precipitation from individually seeded convective clouds.

1971
711
15-136-57-90
Biswas, K.R. and A.S. Dennis, August, 1971, "Formation of a Rain Shower by Salt Seeding", JAM, 10, pp 780-784.

Experimental Design
Finely milled salt particles were released in the updrafts below the cloud base. Results were monitored by radar.

Type of Seeding

350 lb. of NaCl were released below one end of a line of stratocumulus clouds on July 23, 1970.

Meteorological Conditions

An occluded front was followed closely by a 700 mb. trough. Cloud base was 9,000 ft and cloud tops were at 15,000 to 18,000 ft above sea level. Cloud top temperature was near $-2^{o}C$ and updraft speeds below the base were near 3 ms^{-1}.

Response Variables

Taped radar reflectively data

Statistical Techniques

None carried out

Conclusions

Qualitatively, the experiment clearly demonstrated that the introduction of proper size rain embryos at cloud base can sometimes initiate the Langmuir chain reaction of precipitation growth. (A drop of given size would collect smaller droplets lying in its fall path.) Quantitatively, a computer analysis of taped radar reflectivity data indicates the water produced was about 280 acre-feet (340,000m^3). No rain fell from the unseeded portion of the cloud line or from any other clouds within 50 mi.

Comments

Photograph of shower following salt seeding.

712
11-231-53-79
Chappell, Charles F., 1971, "Cloud Seeding Affects on Precipitation Intensity and Duration of Wintertime Orographic Clouds", Proceedings of the International Conference on Weather Modification, Sept. 6-11, Canberra, Australia, pp 121-126.

Experimental Design

This experiment in central Colorado mountain snowfall was randomized with a 24-hour sampling unit.

Type of Seeding

Six ground generators with a seeding rate of 20 grams of Ag I per hour.

Meteorological Conditions

The criterion for an experimental day was a forecast of at least 0.01 inch of precipitation accompanied by 500 mb wind between 210 and 360 degrees.

Response Variables

Sixty-five snowfall observation sites were read daily.

Statistical Techniques
Chi-square tests were used.

Conclusions
This investigation indicates that seeding cold orographic clouds influences the duration more than the intensity of snowfall.

713
14-131-51-87
Dennis, A. S. and Schock, M. R.; December, 1971, "Evidence of Dynamic Effects in Cloud Seeding Experiments in S. Dakota", JAM, 10, pp 1180-1184.

Experimental Design
A randomized crossover design with target areas of approximately 700 mi^2 each. Seeded and unseeded areas during summers of 1966-68.

Type of Seeding
300 $gm\ hr^{-1}$ of Ag I at cloud base.

Meteorological Conditions
Varied

Response Variables
Rainfall and hailfall were collected from a network of 90 stations.

Statistical Techniques
Randomized crossover design (efficient for rejection of null hypothesis). Application of sum-of-squared-ranks test. Gamma distributions were fitted to rainfall occurrences in the target area and in the control areas on seed and no seed days.

Conclusions
Increased growth of seeded clouds and suppression of neighboring clouds at distances of some tens of miles.

714
18-231/235-51/58-85/79
Elliott, Robert D., St. Amand, Pierre, and Thompson, John R., August, 1971, "Santa Barbara Pyrotechnic Cloud Seeding Test Results 1967-70", JAM, Vol. 10, pp 785-795.

Experimental Design
Tests of the effectiveness of ground-released pyrotechnics in enhancing precipitation in storms in Santa Barbara County were conducted during the winter seasons of 1967-70. Selection of convective bands to seed was made on a random basis following declaration of the approach of a seedable band.

Type of Seeding

A series of pyrotechnic candles of LW-83 formulation were used to avoid the disadvantages of Ag I - Na I complex.

Meteorological Conditions

Convective bands (groups of convective cells)

Response Variables

60 recording raingages and soundings taken with GMD-1 radiosonde system prior to band passage.

Statistical Techniques

1) Double ratio of test and control band average precipitation
2) Mann - Whitney U Test

Conclusions

Overall precipitation was considered. The net increase was about 32% for stations distributed over a several hundred square mile area downwind of the point source of nuclei.

[illegible]
11-231- ? -85/87

Mielke, Paul W., Lewis O. Grant, and Charles F. Chappell, Dec., 1971, "An Independent Replication of the Climax Wintertime Orographic Cloud Seeding Experiment", Journal of Applied Meteorology, 10, p 1198-1212.

Experimental Design

The design involves randomized seeding with an experimental period of 24 hours, conducted in wintertime experiments between 1965 and 1970 near Climax, Colorado.

Type of Seeding

Ground generated Ag I at the rate of 20 gm/hr.

Statistical Techniques

The two-sample Wilcoxon and two sample sums-of-squared rank tests were used.

Conclusions

In particular, the agreement in temperature and wind partitions was consistent with a previously reported model which describes seeding effects under various physically defined conditions.

716
18-231-51-79/85
North American Weather Consultants, May, 1971, "Santa Barbara Pyrotechnic Seeding Device Test Program: 1969-70 Season and 1967-70 Summary Final Report", Naval Weapons Center Technical Publication 5093, China Lake, California.

Experimental Design

A randomized design was employed in the Santa Ynez Mountains. A target and control area were determined. The convective band of winter was used as an observation unit. The 1969-1970 season and 1967-1970 cumulative samples are considered. The cumulative samples give sixty-three percent of the total (27 seeded and 27 non-seeded) as the "most seedable category".

Type of Seeding

The LW-83 pyprotechnic device was used at ground level. Ag I output was calculated at 399 gms per unit.

Meteorological Conditions

1) Wind flow must be such that the effects of seeding will fall mainly in the target area.

2) The air mass structure should be such to ensure mixing from the seeding site to the -4°C level or higher.

Response Variables

Over 60 raingauges

Statistical Techniques

1) Double ratio
2) Composite ratio
3) Rank-sum test

Conclusions

1) This seeding mode can be effectively employed provided there is suitable upwind information, supplemented by thermodynamic information.

2) The seeding device was highly effective in increasing precipitation downwind from seeding site.

3) All bands, regardless of seedability when seeded, produced about 50% increases over most of the area.

Comments

Six appendices and fifteen tables are given. Included are precipitation statistics and meteorological statistics. Also a computerized seeding area of effect model was used to predict an envelope of seeding area of effects for the various statistical categories. There areas compared favorably with the observed area.

15-144/143/133-59-90
St. Amand, P., R. S. Clark, T. L. Wright, E. E. Hindman, II, and W. G. Finnegan, 1971, "Modification of Warm Cumulus Clouds with a Hygroscopic Solution", Proceedings of the International Conference on Weather Modification, Sept. 6-11, Canberra, Australia, pp 143-144.

Experimental Design
The purpose was to determine the feasibility of developing warm cumulus modification techniques. Project Gulf Q was conducted at Brownsville, Texas, with operations over the Gulf of Mexico. Untreated warm cumulus clouds were compared with treated warm cumulus clouds.

Type of Seeding
A solution of ammonium nitrate and urea in water was used.

Meteorological Conditions
Cumulus maritime clouds

Response Variables
Visual observations were made.

Statistical Techniques
None

Conclusions
Rapid dumps of the hydroscopic solution into the cloud updrafts can cause rapid dissipation of warm maritime cumulus clouds.

718
15/17-131-57-85/71/83
Simpson, Joanne and William L. Woodley, April, 1971, "Seeding Cumulus in Florida: New 1970 Results", Science, 172, pp 117-126.

Experimental Design
A randomized single and multiple cloud seeding experiment in southern Florida from 15 April to 31 May 1970 and from 29 June and 19 July, 1970 respectively.
There were nine operational days. Altogether twenty-nine single clouds were obtained; 13 seeded, 6 random controls, and 10 radar controls.

Type of Seeding
Airborne pyrotechnic flares dropped into top of cloud.

Meteorological Conditions
Cumulus clouds

Response Variables
Radar rain measurements

Statistical Techniques
Rank-sum test, regression, analysis of covariance.

Conclusions
In the Florida single cloud experiment, the main result of the statistical analysis was that the dynamic seeding effect on rainfall is large, positive, and significant. Multiple clouds results were statistically inconclusive, but appeared promising.

719
17-131-57-85/82/71
Simpson, Joanne, Woodley, William L., Miller, Alan H. and Cotton, Gerald F., June, 1971, "Precipitation Results of Two Randomized Pyrotechnic Cumulus Seeding Experiments", JAM, Vol. 10, pp 526-544.

Experimental Design
A randomized, single cloud, (selection criterion for clouds listed below), dynamic seeding experiment was conducted in South Florida in 1968 with an improved repetition in spring and early summer of 1970. Clouds were randomly selected with unseeded clouds serving as control.

Type of Seeding
Airborne pyrotechnics released Ag I into cloud tops.

Meteorological Conditions (selection criteria for single clouds)
(i) hard, cauliflower-like appearance with tops between 19-26,000 feet.
(ii) isolation from other convective activity.
(iii) minimum supercooled cloud water content of 0.5 gm m^{-3}.

Response Variables
The UM/10cm radar was used to collect precipitation rate data on film. Mean total seeded and unseeded rainfalls were computed and compared for the first 40 min. after seeding and for the entire post-seeding cloud lifetimes until merger or dissipation.

Statistical Techniques
1) Wilcoxon - Mann - Whitney
2) covariate regression
3) analysis of variance
4) analysis of daily means

Conclusions
Qualitatively, the most important conclusions from the statistical analysis of the data is that the dynamic seeding effect on rainfall is large, positive and significant. A quantitative estimate is that seeding increased the amount of precipitation by a factor greater than 3.

7110
11-131-51-71
Smith, E. J., E. E. Adderley, L. Veitch, and E. Turton, 1971, "A Cloud-Seeding Experiment in Tasmania", Proceedings of the International Conference on Weather Modification, Sept. 6-11, Canberra, Australia, pp 91-96.

Experimental Design
One target and three control areas were chosen, and periods of 10 to 18 days were arranged in pairs. One of the periods was randomly chosen and clouds over or approaching the target area were seeded. Conducted from 1964 to 1970 inclusive.

Type of Seeding
Silver iodide was released from airborne generators.

Meteorological Conditions
Varied

Response Variables
A network of 54 raingauges in target and control areas was used.

Statistical Techniques
Multiple regression

Conclusions
Cloud seeding caused an increase in rainfall.

1972
721
11-131-51-85
Brown, K. J. and R. D. Elliott, 1972, "Mesoscale Changes in the Atmosphere Due to Convective Bank Seeding", Third Conference on Weather Modification, June 26-29, Rapid City, S.D., p 313-320.

Experimental Design
The randomized seeding and observation unit was a convection band embedded in a general storm system. This is the Santa Barbara Project. The intent of this paper is to present physical inferences drawn from a statistical analysis of a precipitation gauge network.

Type of Seeding
LW-83 pyrotechnic flare, producing 400 gms of silver iodide in a three minute period.

Meteorological Conditions
General storm system with convective bands.

Response Variables
A network of 168 raingauges.

Statistical Techniques
Rank-sum test

Results
The data gave rather conclusive statistical evidence that this seeding has altered the precipitation pattern. The "post hoc" physical evaluation leads to some interesting patterns. One of the more conclusive ones was the apparent increase in the time duration of a seeded band at a given point.

722
11-131-51-85
Chappell, Charles F., 1972, "Airborne Seeding of Wintertime Wastach Mountain Clouds during Project Snowman", Third Conference on Weather Modification, June 26-29, Rapid City, S. D., pp 129-132.

Experimental Design
A 4-hour sampling unit with randomization in blocks of two was employed. The broad objective was to investigate the feasibility of a precipitation management for the Wastach Mountain area of NE Utah. This paper summarizes the winter seasons of 1969-1971.

Type of Seeding
Ag I pyrotechnic (Olin R-15) mounted on an aircraft.

Meteorological Conditions
Six criteria were required, which include cloud base, cloud cover, cloud depth, 700 mb wind direction and temperature.

Response Variables
8-inch orifice accumulation gauges

Statistical Techniques
Rank sum test

Conclusions
The results support other cold orographic cloud experiments and strongly suggest that annual snowpack could be increased with discriminatory cloud seeding programs.

723
15-144-57/59-90
Cunningham, Robert M. and Morton Glass, 1972, "A Warm Cumulus Modification Experiment", Third Conference on Weather Modification, June 26-29, Rapid City, S. D., pp 175-178.

Experimental Design

This project was a series of measurement and seeding experiments in warm cumulus clouds off the east coast of Florida, conducted during the month of Sept., 1971, two evaluation methods were to be used on the preliminary data. One was a balance between seeded and unseeded clouds and the other was use of a convective cloud model.

Type of Seeding

Airborne encapsulated urea.

Meteorological Conditions

Cumulus clouds were growing and rain was not falling.

Response Variables

Radar, air measurements and photography.

Statistical Techniques

None given.

724
11-131-51/57-87/83
Dennis, A. S., J. W. Gelhaus, and M. R. Schock, 1972, "Rainfall Anomalies in a Randomized Seeding Project", Third Conference on Weather Modification, June 26-29, Rapid City, S. D., p 300-303.

Experimental Design

The project operated on a randomized basis from June 1 to August 15 in 1969 and 1970. A 2-day block was selected at random from each 8-day period and was reserved as no-seed days. Target and control areas were in northwestern S. Dakota and southwestern N. Dakota. This paper presents evidence of a bad draw in a randomized seeding project and describes an attempt to evaluate seeding effects in the presence of a bad draw.

Type of Seeding

Airborne acetone generators

Meteorological Conditions

Varied summertime conditions

Response Variables

110 raingauges and S-band radar.

Statistical Techniques

Sum-of-squared-ranks, and application of covariance analysis.

Results

Analysis shows contrary to initial impressions that cloud seeding may have had a positive effect. The experiment confirms that randomization does not by itself insure a successful experiment. It is essential that controls be provided to predict target area rainfall in the absence of seeding. Cloud models appear necessary as an aid in sorting out effects of Ag I seeding.

725
12-231-59-85
Dessens, Jean and Jean-Pierre Lacaux, 1972, "Ground Seeding For Hail Prevention in South-Western France: Possible Overstepping of an Economical Efficiency Level from 1963", Third Conference on Weather Modification, June 26-29, Rapid City, S. D., pp 268-271.

Experimental Design

The project is non-randomized, all the potential cases being treated. A "target-control historical" design is used. The project started in 1961 and by 1970 an area of 7 million hectares (1 hectare = 2.5 acres) in the Aquitain Basin of South-West France.

Type of Seeding

Silver iodide ground generators

Meteorological Conditions

Hailstorm conditions

Response Variables

Crop-loss data in target area.

Statistical Techniques

Rank sum test

Conclusion

Results show significant decrease of hail damage in the target area.

726
18-131/142/231-51-79/78/85
Elliott, Robert D. and John R. Thompson, Feb., 1972, "Santa Barbara Convective Seed Test Program: 1970-71 Season and 1967-71 Summary", Naval Weapons Center Technical Publication 5308, China Lake, California.

Experimental Design

A randomized design was employed in the Santa Ynez Mountains. A target and control area were determined. The convective band of winter was used as an observation unit. The 1970-1971 season and 1967-1971 cumulative samples are considered. The cumulative total after 1971 was 107 convective band units. Also this report contains limited results of the first year's operation of aerial seeding.

Type of Seeding

The LW-83 Ag I pyrotechnic was used at the ground. The two airborne seeders were a continous burning of a silver iodide-ammonium iodide-acetone solution. The aerial Ag I output was 0.24 gm/sec. The ground Ag I output was 2.22 gm/sec.

Meteorological Conditions

1) Wind flow must be such that the effects of seeding will fall mainly in the target area

2) The air mass level should be such to ensure mixing from the seeding site to $-4^{o}C$ level or higher.

Response Variables

Eighty raingauges.

Statistical Techniques

1) Double ratio
2) Single ratio
3) Rank-sum test

Conclusions

Data added for this year (1970-1971) have done nothing to change the conclusions reached earlier. These conclusions were: 1) Seeding convective bands was a practical and efficient means of cloud seeding. 2) The LW-83 pyrotechnic was highly effective in increasing precipitation downwind from the seeding site. Due to small sample size, no conclusions can be drawn from the aerial seeding operations.

727
11- ? -62-90
Goyer, Guy G. and Janet M. Wood, 1972, "The Radar Climatology of Thunderstorms in Northeastern Colorado", Third Conference on Weather Modification, June 26-29, Rapid City, S.D., pp 248-253.

Experimental Design

The experiment was an attempt to suppress all hail in a Protected Area (1536 Km^2) on randomly selected days. The data is from the summers of 1969, 1970, and 1971 in Colorado.

Response Variables

Hailpad network

Statistical Techniques

None were given. However it was noted that hail days tend to occur in series of 2 up to 5 days, and this non-random distribution must be taken into account in the design of the statistical experiments.

Conclusion

The variability of data presented in this paper shows the need for many more similiar analysis in order to design a cloud-seeding operation to meet the requirements of a statistical experiment.

728
11-131/135-57/51-75/85
Grant, Lewis O., James M. Fritsch, and Paul W. Mielke, Jr., 1972, "Randomized Seeding of Continental Convective Clouds Near Climax, Colorado", Third Conference on Weather Modification, June 26-29, Rapid City, S. D., pp 216-221.

Experimental Design
The experimental unit was the 24-hour period from 9 am to 9 am. Randomization was employed in defining the seeded and non-seeded units. Only summer results are presented in this paper. The project operated during 1966-1970 near Climax, Colorado.

Type of Seeding
Needle-type generators burning an Ag I - Na I solution.

Meteorological Conditions
A forecast of 0.01 inch of rain in 24-period.

Response Variables
Two radar units, plus a network of 8" rain gauges.

Statistical Techniques
Chi squared. Rank sum test.

Conclusions
Large changes (both positive and negative) in the precipitation efficiency of Continental cumulus clouds are suggested.

729
15-131/135/142-59-90
Henderson, Thomas J., 1972, "Results From Comparisons Between the Field Applications of Ag I - Na I and Ag I - NH_4 I Solutions in Airborne Generators on a Hail Suppression Program in Kenya", Third Conference on Weather Modification, June 26-29, Rapid City, South Dakota, pp 333-336.

Experimental Design
Beginning in 1967, a Hail Suppression Program was initiated in Kenya near Nairobi, Kenya. To date (1972) 950 operational days were accumulated with seeding applied to more than 3600 individual cumulus clouds. All potential hail producing cumulus clouds are treated.

Type of Seeding
Airborne generators of either Na I - 2 Ag I or NH_4 I - 2 Ag I

Meteorological Conditions
Convective cumulus clouds.

Response Variables
Hail damage reports to tea

Statistical Techniques
Comparisons of damage per hail instance of Na I - 2 Ag I and NH_4 I - 2 Ag I.

Results
The number of both damaging and non-damaging hail instances is significantly less with the NH_4 I - 2 Ag I solution. The NH_4 I - 2 Ag I solution appears to be 75% more effective than Na I - 2 Ag I solution when dispersal at cloud base is in a temperature regime warmer than + 4C.

7210
11-131-59-72
Henderson, Thomas J. and Stanley A. Changon, 1972, "Results From an Application Program of Hail Suppression in Texas", Third Conference on Weather Modification, June 26-29, Rapid City, S. D., pp 260-267.

Experimental Design
A two-county target area with an adjacent county as control area was employed. All events were seeded. The project was located in northwest Texas during the May-October periods of 1970 and 1971.

Type of Seeding
4% solution of Ag I by weight was used in liquid fuel generators.

Meteorological Conditions
Clouds that would give birth to, and allow growth of hailstones.

Response Variables
Hail-day data and crop-hail insurance loss data.

Statistical Techniques
Correlations. Comparisons of insurance values.

Conclusions
Results indicate that for target area the loss-cost values were below average. However, it is suggested that a 4-5 year period would be needed for this to be statistically significant at the 5% probability level.

7211
11-238/239/133-60-84
Huff, F. A. and S. A. Changnon Jr., Aug., 1972, 'Climatological Assessment of Urban Effects on Precipitation at St. Louis', JAM, 11, p 823-842.

Experimental Design

An investigation was made of urban effects on precipitation in and downwind of St. Louis through use of long-term climatic records within a radius of 50-75 mi. of the city. Based on radar climatological studies, two potential urban effect areas and two no-effect (control) areas were designated.

Potential Causes of Urban Effects on Precipitation Amounts

1) urban heat island
2) modification of microphysical and dynamical processes in clouds through addition of ice nuclei
3) increase of low level mechanical turbulence from urban-created obstructions
4) modification of the low level atmospheric moisture content by stocks and cooling towers

Meteorological Conditions

St. Louis has a continental humid climate, subject to extremes of precipitation, temperature, and various forms of severe local weather.

Response Variables

The primary source of data was the climatological records of precipitation published by the Enviromental Data Service of NOAA. This was supplemented by 5 downwind stations operated by US Army Corps of Engineers.

Statistical Techniques

Spatial pattern analysis on several different subtopics were made. (eg., total precipitation on monthly and seasonal basis, frequency and intensity of rainfall, hail).

Conclusions

Quantitative results showed that all forms of pattern analysis supported positive departures in downwind area. These results appear to support thermal effects as a factor in urban modification of natural precipitation.

7212
11-231-51-85/87
Keyes, C. G. Jr., D. Rottner, F. D. Stover, and R. D. Wilkens, 1972, "An Evaluation of the Results of Four Years of Randomized Seeding in Northern New Mexico", Third Conference on Weather Modification, June 26-29, Rapid City, S. D., pp 137-142.

Experimental Design

This was a randomized seeding project to study orographic snowfall in the vicinity of Cuba, New Mexico. Seeding was carried out in units of 24 hours during the winter months starting in 1968. The target area was Sierra Nacimiento and Jemez Mountain ranges between Cuba and Los Alamos, New Mexico.

Type of Seeding
Ag I ground generators

Meteorological Conditions
At least 0.01 inch of rain was forecast.

Response Variables
Twenty-Five hourly recording precipitation gauges were used.

Statistical Techniques
The two sample Wilcoxon and two sample sum of squared rank tests were used.

Conclusions
The results are partitioned into 500 mb temperature, cloud top temperature, time of day, and 700 mb. wind direction. Each area is discussed separately.

7213
11-131/135-57/55/51-90
Kopcielski, Alexander and A. S. Dennis, 1972, "Seeding Effects in Convective Clouds in Western South Dakota", Third Conference on Weather Modification, June 26-29, Rapid City, S. D., pp 186-191.

Experimental Design
This is description of the results of the lst three years (1969-1971) of a randomized experiment for summer convective clouds in the Northern Great Plains. This project uses a moveable target area. Randomization was applied with one-third of the cases reserved as no-seed days. Test cases were: No-seed, Ag I-seed, Na I-seed.

Type of Seeding
Ag I flares and finely ground salt.

Meteorological Conditions
Small, isolated cumulus to groups of towering cumulus already showing radar echoes.

Response Variables
Radar, instrumented aircraft, and a rain gauge network.

Statistical Techniques
Analysis of echoes, radar rainfall, area rainfall, and hailfall is presented.

Conclusions
Tentative results suggest increases in precipitation due to seeding but due to the variability of cumulus precipitation the results are not yet statistically significant.

7214
11-231-51/57-89/87
Mitchell, V. L., A. B. Super, R. H. Yaw, 1972, "Preliminary Results of a Randomized Winter Orographic Cloud Seeding Experiment in the Northern Rocky Mountains", Third Conference on Weather Modification, June 26-29, Rapid City, S. D., pp 125-128.

Experimental Design

A 24 hr time unit was used. When the precipitation probability was 20% a randomized list of seed-no seed was consulted to determine whether or not to seed. The purpose was to determine under which meteorological conditions and to what extent cloud seeding can influence snowfall in the Northern Rocky Mountains, in particular the Bridger Mountains near Bozeman, Montana.

Type of Seeding

Silver iodide from ground generators.

Meteorological Conditions

Precipitation probability of 20% or more.

Response Variables

31 large orifice weighing precipitation gauges (serviced weekly), 3.2 cm radar.

Statistical Techniques

Two sample Wilcoxon rank test and two sample sum-of-squared rank test.

Conclusion

Preliminary results lend credence to the suggested seeding effect.

Comments

These are preliminary results based on a total of 203 days.

7215
22-131-57/59-90
Summers, Peter W., 1972, "The Silver Fallout Patterns in Precipitation from Seeded Convective Storms", Third Conference on Weather Modification, June 26-29, Rapid City, S. D., pp 279-286.

Experimental Design

The design emphasizes physical understanding rather than statistical inference. Each individual experiment is treated as a separate case. The project was carried out in Alberta during summers of 1970 and 1971.

Type of Seeding

Droppable pyrotechnic flare containing Ag I.

Meteorological Conditions
Hailstorms

Response Variables
Radar, rain and hail patterns reported by farmers, time-lapse photography, and hail damage statistics.

Statistical Techniques
None

Conclusions
It is suggested that a lateral buffer zone of at least 60 mi may be required between the target and control areas for crossover randomized experiments in convective situations, to avoid the possibility of contaminating the control area.

7216
18-131-51/57-
Thompson, John R., 1972, "Santa Barbara Aerial Seeding Program 1971-72", Third Conference on Weather Modification, June 26-29, Rapid City, S.D., p 325-332.

Experimental Design
Randomization based on 48-hour time blocks was adopted.

Type of Seeding
LW-83 pyrotechnic flares from aircraft.

Meteorological Conditions
Convective bands

Response Variables
Rain-gauges & Raytheon Model 2502 X-band radar.

Conclusions
The statistically significant increases in precipitation have led to undertake phase II. The first seasons results (Nov. 1971 - April 1972) had been completed with encouraging results, but samples were inadequate for analysis.

7217
17-131-51/57-85
Woodley, William Lee and Joanne Simpson, 1972, "Results of Dynamic Multiple Cloud Seeding in Florida", Third Conference on Weather Modification, June 26-29, Rapid City, South Dakota, pp 292-299.

Experimental Design

The EML (Experimental Meteorology Laboratory) designed and executed a pilot project in multiple cloud seeding over South Florida during June and July of 1970 and 1971. The design consisted of a fixed target area with randomization weighted two to one in favor of seeding in 1970 and a 50-50 randomization in 1971. Suitable days for seeding are determined from an EML model. Also a "floating target" was used.

Type of Seeding

Ag I flares, 60 used (each with 50 grams of Ag I).

Meteorological Conditions

Cumulus clouds

Response Variables

Radar and raingauges

Statistical Techniques

Rank sum test

Results

Twelve area experiments were conducted in 1970 and 1971, 7 seeds and 5 controls. Due to small samples, there is the suggestion, but not proof, that seed days were more successful than the controls.

1973
731
11-331/332-53-71/83
Beaumont, R. T., September 1973, "Cloud - Seeding Analysis in Oregon", BAMS, 34, pp 298-303.

Experimental Design

Two separate cloud-seeding operations in Oregon were used. (Southern Oregon Cascades, Winters 1949-50, 1951-52; Tri-counties area, September 1950-51, 1951-52). Target areas were compared with non-seeded control areas.

Type of Seeding

Airborne and ground generators using silver-iodide and carbon-dioxide.

Meteorological Conditions

Varied

Response Variables

Maximum accumulated water content of the snow on the target area and on a non-seeded control area.

Statistical Techniques

Scatter Diagrams, regression analysis, analysis of covariance.

Conclusions

From the analysis there appears no supporting evidence that cloud-seeding has materially increased precipitation in target areas.

732
17-131/142-51-78/85
Elliott, Robert D. and John R. Thompson, July, 1973, "Santa Barbara Convective Band Seeding Test Program: Phase II. 1970-72 Summary", Naval Weapons Center Technical Publication 5519, China Lake, California.

Experimental Design

This report covers the two-year summary of the aerial seeding phase of the Santa Barbara program to investigate the effectiveness of seeding the convective bands of winter. In addition, this report contains new analysis of data collected during the four years of previous ground pyrotechnic seeding. The total aerial seeding sample for the two years was six seeded and eight not-seeded bands. A randomization based a 48-hour time block was used.

Type of Seeding

Aerial seeding using an Ag I - NH_4 I - acetone solution was employed.

Meteorological Conditions

In the opinion of the project director (after all available information has been considered) that a convective band is suitable in character and moving toward the coast he declares a "go" situation.

Response Variables

A network of 89 raingauges were employed for analysis.

Statistical Techniques

1) Single ratio
2) Rank-sum test

Conclusions

1) The data gathered during four years of seeding convective bands with pyrotechnics at a ground based source has provided statistical evidence that seeding has altered precipitation. Changes within the seeded bands are generally in the form of increases in precipitation of 50% to 100% in primary seeding zone.
2) Aerial seeding analyses indicate a decrease in precipitation and duration in the target area, with an increase 75 miles east of the seeding area.

Comments

Nine appendices and four tables are included.

733
11-231-51-81
National Center for Atmospheric Research, December, 1973, "NHRE (National Hail Research Experiment): A Modern Prototype Experiment", Atmospheric Technology, 4.

Experimental Design

A randomized process was used for choosing Seed versus No-Seed days allowing the test area to serve as its own control. Whether to seed or not to seed was chosen randomly. This was a 5-year program but this article contains only results from 1972, the first full year of full-scale field operations held in a protected area on the Colorado - Nebraska border (~1600 km^2).

Type of Seeding

Airborne Ag I rockets and flares (100g each) for seeding within and at cloud base, respectively.

Meteorological Conditions

Storm system

Response Variables

Rain and hail accumulation and, in some instances, rain and hail rates.

Statistical Techniques

None given, although goal objectives were established (eg. statistical evaluations of efficiency, multivariate statistical analysis).

Conclusions

This project seems to have been well developed and organized with objectives well established.

Comments

Most articles were written by students involved in project.

1974
741
18-331-51/57-75/80
Brown, Keith J., Robert D. Elliott, and John R. Thompson, 1974, "The Seeding of Convective Bands", Fourth Conference on Weather Modification, November 18-21, Fort Lauderdale, Fla. p 7-12.

Experimental Design

Descriptions of Phase I and Phase II of the Santa Barbara projects are given (convective band seeding).

Type of Seeding

Ground based Ag I for Phase I, airborne Ag I for Phase II.

Meteorological Conditions

Convective Bands

Response Variables

Rain gauges and radar

Statistical Techniques
Chi-square test, median ratio test.

Results
The magnitude of the precipitation increase is of the order of 50 to 100% within seeded bands and 25 to 50% for the storm total.
Three distinct areas of increased precipitation have been identified. The first is "the primary seeding zone." The second is a "downwind area." The third area has been termed the "Mesoscale Dynamic Effect."
The bands tend to widen and possibly slow down after seeding.

742
11-131-51/57-85/83/71
Dennis, A. S., J. H. Hirsch, and D. E. Cain, 1974, "Evaluation of Effects of Silver Iodide Seeding in Project Cloud Catcher", Fourth Conference on Weather Modification, November 18-21, Fort Lauderdale, Fla., pp 24-27.

Experimental Design
A cloud model is used to help explain apparent effects of silver iodide seeding on convective clouds of the Northern Great Plains. The analysis is limited to the 33 no-seed and 18 silver iodide test cases in 1969-1970 of Project Cloud Catcher.

Type of Seeding
3 silver iodide flares of 120 g silver iodide released by aircraft below cloud base.

Meteorological Conditions
Convective clouds

Response Variables
Raingauge and radar

Statistical Techniques
Rank-Sum test, covariance test, regression lines.

Conclusions
The no-seed version of the cloud model predicts tops of the no-seed cases with a standard error of one kilometer. The silver iodide version predicts higher tops then the no-seed madel. Cloud tops predicted by silver iodide model are not statistically different from observed values of maximum echo height.

743
11-231-51-71/76/78
Elliott, Robert D. and Russell W. Shaffer, 1974, "Alterations in Orographic Water Balance Due to Cloud Seeding", Fourth Conference on Weather Modification, November 18-21, Fort Lauderdale, Fla., pp 420-424.

Experimental Design

Data from the Colorado River Basin Pilot Project was used. Three years of hourly precipitation and three-hourly sounding data are available for seeded 24-hour experimental days. Data was stratified and analyzed for key precipitation parameters.

Type of Seeding

Ground generated silver iodide.

Response Variables

Rain gauges.

Statistical Techniques

Multiple regression, F-test, ratios of observed seeded to observed not seeded precipitation.

Conclusions

Taken overall, the cloud depth was the most important factor in three-hourly precipitation rates, followed by the seed/no-seed parameter.

744
15-140-59-90

Henderson, Thomas J., and William Finneagan, 1974, "Results from the Field Application of Morpholine and Ethylamine to Small Cumulus Clouds", Fourth Conference on Weather Modification, November 18-21, Fort Lauderdale, Fla., pp 210-213.

Experimental Design

Twelve tests were conducted along the Sierra Range in California during the period 16-29 May 1973. The total tests were divided evenly with 6 cases each of ethylamine and morpholine. A summary of application tests is given.

Type of Seeding

Airborne liquid fuel generators with mixture released at cloud base.

Meteorological Conditions

Small cumulus clouds (tops less than 20,000 ft.).

Response Variables

Visual aircraft observations

Statistical Techniques

None

Conclusions

The effects described are so striking, this approach to precipitation management may well be one of the most important and immediately useful contributions to appear since the discovery of silver iodide and other materials effective in the modification of liquid water/ice crystal formation and growth mechanisms.

745
14-231-51-90
Hill, Geoffrey E., 1974, "Results of a Cold Orographic Cloud Seeding Experiment in the Northern Wasatch Mountains", Fourth Conference on Weather Modification, November 18-21, Fort Lauderdale, Fla., pp 462-467.

Experimental Design

Two experiments were conducted in the Northern Wasatch Mountains as part of project Skywater. This paper presents a report of the second (ongoing) experiment. Random seeding was performed on clouds that met certain meteorological criteria. Two approaches were used to develop precipitation predictors. An experimental event consisted of an eight - hour period half of which was designated seeded and the other half unseeded.

Type of Seeding

Three mountain top silver - iodide generators.

Meteorological Conditions

Precipitation was primarily orographically induced. The surface to 500 mb., relative humidity exceeded 70%, and wind at both 700 and 500 mb. was between 220 and 320 degrees.

Response Variables

Eleven precipitation stations.

Statistical Techniques

Comparisons of observed to predicted values.

Conclusions

When moist air flows over a mountain barrier, in the absence of specific meteorological disturbances, precipitation in the high mountains is well-related to the wind and moisture fields. Although not enough data has been collected, the overall methods appear promising.

746
14-136-51/57-85
Krishna, K., A. S. Ramachandra Murty, R. K. Kapoor, and Bh.V. Ramana Murty, 1974, "Results of Warm Cloud Seeding Experiments in Three Different Regions in India During the Summer Monsoon of 1973", Fourth Conference on Weather Modification, November 18-21, Fort Lauderdale, Fla., pp 79-84.

Experimental Design

Experiment I was a randomized cross over design, conducted on the Deccan Plateau. The north and south sectors were each 1600 km^2 with a buffer in between.

Experiment II was conducted on maritime cumulus. An isolated cloud served as control.

Experiment III was a 13,000 km^2 target area with two independent control areas.

Type of Seeding
Airborne common salt mixed with soapstone

Response Variables
Rain gauges and radar

Statistical Techniques
Mann-Whitney Test

Conclusions
A positive trend was indicated on 7 of 13 pairs of days in Experiment I. The trend in Experiment III was positive. Neither I nor III is statistically significant. The details of Experiment II are given.

747
22-238-59-90
Lee, M.F., March, 1974, "Cumulus Clouds from a Stubble Fire", Weather, 29, p 102.

A photograph is given of cumulus cloud observed over the Berkshire Downs on 24 August 1975.

748
11-141-59/57-90
Lewis, Billy M. and Harry F. Hawkins, 1974, "An Experiment to Test the Modifying Effects of Hydrophilic Powder on Maritime Cumulus Clouds", Fourth Conference on Weather Modification, November 18-21, Fort Lauderdale, Fla., pp 85-88.

Experimental Design
A randomization table of seeding versus non-seeding was tabulated prior to flight days by the National Hurricane Research Laboratory. Four clouds on two different days (Oct. 11 & 13, 1972) were selected. Five clouds were seeded, three were not.

Type of Seeding
Airborne portland cement.

Meteorological Conditions
Active cloud tower

Response Variables
Visual and radar observations

Statistical Techniques
None

Conclusions
It was clear that in the shearing environment of these experiments nothing very startling became apparent. Recommendations are given to repeat the project but include instruments to measure more accurately the vertical shear.

749
11-131-51-85
Miller, J. R., Jr., E. I. Boyd, and R. A. Schleusener, 1974, "Hail Suppression from Western North Dakota", Fourth Conference on Weather Modification, November 18-21, Fort Lauderdale, Fla., pp 139-142.

Experimental Design
The North Dakota Pilot Project (NDPP) was a four-year cloud seeding project conducted during the summer months of 1969 through 1972 in western North Dakota. 75% of the days were chosen at random to be seeded, the other 25% were designated as no-seed days.

Type of Seeding
Airborne silver iodide generators flying below cloud base.

Meteorological Conditions
Hail threat conditions

Response Variables
Hail pads and rain gauges with density of one per 90 km^2 were used in Mckenzie County and one per 260 km^2 in Mountrail and Ward counties. Also insured crop hail analysis data was used.

Statistical Techniques
Rank-sum test, ratio of average impact energy to average rainfall, regression lines using radar data.

Conclusions
Hail impact energy was not significantly different (at 10% level) on seeded days or unseeded days. Crop hail damage was significantly less. Rainfall ratio was greater on seed days than no-seed days.

7410
11-131-57-90
Riggio, Robert F. and John T. Carr, Jr., 1974, "An Evaluation Design of a Commercial Cloud Seeding Program", Fourth Conference on Weather Modification, November 18-21, Fort Lauderdale, Fla., pp 329-333.

Experimental Design
A privately funded cloud seeding program in West Texas was initiated in 1971. The target area was 3,750 mi^2. A randomized system of three-fourths seeded and one-fourth unseeded was adopted.

Type of Seeding
Airborne silver iodide flares.

Meteorological Conditions
Summer Cumulus

Response Variables
M-33 radar system. This system has separate 10-cm (S-band) and 3-cm (X-band) units.

Statistical Techniques
There is discussion of parametric and nonparametric techniques.

Conclusion
Actual statistical procedures to be applied to the data should not be decided until after the data have been compiled and best fitted to some sort of distribution.

7411
11-131-51-85/87
Rottner, Donald, Stanley R. Brown, and Olin H. Foehner, 1974, "The Effect of Persistence of Ag I on Randomized Weather Modification Experiments", Fourth Conference on Weather Modification, November 18-21, Fort Lauderdale, Fla., pp 301-306.

Experimental Design
Both the Jemez Research Project and the Upper Colorado experiment in the San Juan Mountains were randomized - 24 hour winter orographic experiment designs. Both experiments made the assumption that turning off generators before the end of an experimental day would allow sufficient time for all seeding materials to be transported out. This paper is an attempt to check the validity of that statement.
Meteorological Conditions
Winter storms

Response Variables
6-hour precipitation values

Statistical Techniques
Wilcoxon and sum of squared ranks tests

Conclusions
It seems that the design criterion of a wash out period of 2 hours as in the Upper Colorado experiment or 3 hours as in the Jemez experiment, or even a 12-hour period, is questionable.

7412
11-131-54/55-72
Sax, Robert I., 1974, "On the Microphysical Differences between Populations of Seeded vs. Non-Seeded Florida Cumuli", Fourth Conference on Weather Modification, November 18-21, Fort Lauderdale, Fla., p 65-68.

Experimental Design
This paper presents sets of microphysical data obtained on three seed and five no-seed days during the Experimental Meteorology Laboratory's randomized 1973 Florida Area Cumulus Experiment (FACE).

Type of Seeding
Pyrotechnic flares (Ag I)

Meteorological Conditions
Cumulus clouds

Response Variables
Liquid water and ice particle concentration were measured.

Statistical Techniques
Correlation

Conclusions
The primary conclusion is that microphysical differences between seeded and non-seeded clouds are not obvious. Detailed case studies are needed to determine evolution of the water-ice budget between seeded and non-seeded towers.

7413
15-131-57/51-74/85
Simpson, Joanne and William L. Woodley, 1974, "Florida Area Experiments 1970-1973 Rainfall Results", Fourth Conference on Weather Modification, November 18-21, Fort Lauderdale, Fla., pp 58-64.

Experimental Design
In Sept. 1973, the fourth summer of randomized cloud seeding in a 1.3×10^4 km^2 target area in south Florida was completed. In the summer of 1973, a more intensive effort was undertaken called FACE (Florida Area Cumulus Experiment).

Type of Seeding
Airborne silver iodide pyrotechnic flares (20-200 gms per cloud)

Meteorological Conditions
Neighboring cumuli.

Response Variables
Radar with adjustments from five gauge clusters.

Statistical Techniques
Bayesian analysis, non-parametric tests, t-test

Conclusions
The sample is too small for even tenative conclusions. However data suggest that the seeding factor is positive for floating days. For total target days with "marching" echoes it is positive, but results for total target days without significant advection does not support the hypothesis.

7414
11-231-51-65
Super, Arlin B. and Heimbach, James A., Jr., 1974, "Statistical Evaluation of the Bridger Range Cloud Seeding Experiment", Fourth Conference on Weather Modification, November 18-21, Fort Lauderdale, Fla., pp 425-430.

Experimental Design
A randomized winter orographic cloud seeding experiment was conducted in the Bridger Mountain Range of southwestern Montana during the winters of 1969-1972. The basic experimental unit was the 24-hour day. The primary target area was the Bangtail Ridge and valley beyond.

Type of Seeding
Ag I ground generators

Meteorological Conditions
The probability of precipitation for the Bozeman airport was forecast as greater than 20%.

Response Variables
32 Rain gauge network

Statistical Techniques
Wilcoxon rank sum test

Conclusion
Results suggest that seeding caused precipation at the valley stations when none would have occured naturally. There was also a less pronounced suggestion of this effect at the higher elevation gauges.

1975
751
11-131/135-51-75/76/85
Dennis, A. S., J. R. Miller, Jr., D. E. Cain, and R. L. Schwaller, Aug., 1975, 'Evaluation by Monte Carlo Tests of Effects of Cloud Seeding on Growing Season Rainfall in North Dakota', JAM, 14, pp 959-969.

Experimental Design

A randomized cloud seeding experiment was conducted in western North Dakota each summer from 1969 through 1972 to test the effects of seeding on hail and rainfall. The target area was 2750 mi^2. 25% of the days were reserved in advance as no-seed days. Data was analyzed under a number of stratification methods.

Type of Seeding

In 1969-72 seeding varied from as little as 10 to 20 g hr^{-1} of Ag I (small cumulus) to 1kg hr^{-1} (suppression of large hail storms) of Ag I, in 1969-70. A 3% silver iodide-sodium iodide in acetone solution was burned.

Meteorological Conditions

Varied

Response Variables

Twelve hour rain totals were used from seed and no-seed days provided by 67 raingauges located in McKenzie County, N. D. with a density of approximately 1/35 mi^2.

Statistical Techniques

Chi-square, F-distribution, rank sum test. The Monte Carlo evaluation was used to set significance levels for the above.

Conclusions

The results suggest a potential for about 1 inch of extra rainfall per growing season by Ag I seeding.

Comments

A detailed report of the North Dakota Pilot Project is available from South Dakota School of Mines and Technology.

752
18-131/142-51/57-79/78/85
Elliott, Robert D. and John R. Thompson, March 1975, "Santa Barbara Convective Band Seeding Test Program", Technical Publication 5712, China Lake, California.

Experimental Design

This report is a summary of the aerial seeding phase (Phase II) of the Santa Barbara program to investigate the effectiveness of seeding the convective bands of winter. Randomization based on 48-hour time block was used along with a target and control area. A total of 14 seeded and 17 non-seeded cases are analyzed.

Type of Seeding

The primary seeding made during Phase II was aerial seeding with an acetone-Ag I - NH_4I burner. (Ag I output ~ 700 grams per hour) Ground seeding was also continued during Phase II as a backup. However newly developed acetone - Ag I burner was used (Ag I output ~ 350 grams per hour).

Meteorological Conditions

After consideration of data, a convective band is determined to be suitable for seeding and moving toward the coast, project personnel are alerted and dispatched to their operation stations.

Response Variables

1) A network of 104 raingauges were available for analyses.
2) Radar was employed to provide means for monitoring and recording the band movement over raingauge - intensity records.
3) Barometric pressure recorders.

Statistical Techniques

1) Single Ratio
2) Double Ratio
3) Rank-sum test

Conclusions

1) Aerial Seeding with Ag I - NH_4 I - acetone is an effective means of enhancing precipitation.
2) There is evidence of downwind effects some 100 to 140 Kilometers from the seeding area.
3) Evidence is presented that shows a reduction in surface pressure for the seeded bands.

Comments

Eight appendices and four tables are presented.

753

Hobbs, Peter V., Aug., 1975, "The Nature of Winter Clouds and Precipitation in the Cascade Mountains and their Modification by Artificial Seeding. Part I: Natural Conditions", JAM, 14, p 783-804.

This is Part I of a 3 part Report, and gives a description of meteorological conditions.

754
19-131/132-53/57-90
Hobbs, Peter V. and Lawrence F. Radke, Aug., 1975, "The Nature of Winter Clouds and Precipitation in the Cascade Mountains and their Modification by Artificial Seeding; Part II: Techniques for the Physical Evaluation of Seeding", JAM, 14, p 805-818.

Experimental Design
The experiment was carried out when conditions appeared suitable for artificial modification of snowfall by cloud seeding. Target on the ground for snowfall modification was about 90 km^2.

Meteorological Conditions
Possible snowfall clouds.

Response Variables
Measurements and observations made at a number of stations; Doppler radar.

Conclusions
The effects of heavy seeding on the clouds were generally pronounced and measureable.

755
19-131/132-53/57-90
Hobbs, Peter V., Aug., 1975, "The Nature of Winter Clouds and Precipitation in the Cascade Mountains and their Modification by Artificial Seeding. Part III: Case Studies of the Effects of Seeding", JAM, 14, p 819-858.

Experimental Design
Three case studies of the effects of artificial seeding from the air on cloud structure and snowfall on the ground in the Cascade Mts. Target area of 90km^2.

Meteorological Conditions
Strato cumulus or cumulus clouds

Type of Seeding
AgI and dry ice by airplane.

Response Variables
Airplance and ground (as described in Part II) observations.

Conclusions
Snowfall across the Cascade mountains can be redistributed and increased by artificial seeding.

756
12-231-51-85/87
Rottner, Donald, Stanley R. Brown, and Olin H. Foehner, August, 1975, "The Effect of Persistence of Ag I on Randomized Weather Modification Experiments", JAM, 14, pp 939-945.

Experimental Design

The hypothesis was tested that Ag I may persist for long periods of time and contaminate control days when these control days immediately follow a seeded day. Two randomized weather modification experiments (Colorado River Basin, Hemez Mountains) were used. Data sets were broken down from 24 hr to 6 hr events and the persistence of Ag I for 6 hrs following seeding was tested.

Type of Seeding

Seeding was done with ground based silver iodide - acetone generators. (20 gm hr^{-1} each).

Meteorological Conditions

No stratification of meteorological parameters such as 500 mb temperature, cloud top temperature, etc were used. Only cases where no-clouds or winds out of specifications were excluded from the populations.

Response Variables

Recording precipitation raingauges were used in subarea 1(10) and subarea 2(9) in the Colorado River Basin Area. 30 gauges were used in Jemez Mountains.

Statistical Techniques

The two populations (seed and no-seed) were tested using the Wilcoxon test and sum of squared ranks.

Conclusions

Qualitative results which indicate that the design criterion of a washout period of 2 hr (Colorado) and 3 hr (Jemez) or even a 12 hr. period are questionable.

757
17-231-57-85/87/74
Simpson, Joanne and William L. Woodley, August, 1975, "Florida Area Cumulus Experiments 1970-1973 Rainfall Results", JAM, 14, pp 734-744.

Experimental Design

A randomized dynamic cumulus seeding in a 1.3 $X10^{4}km^{2}$ target area in South Florida - 14 seed and 23 control cases are available. Seed control rainfall comparisons are made for "floating" and total targets.

Type of Seeding

Neighboring cumuli are seeded with airborne silver iodide pyrotechnic flares (100 - 1000 g per cloud).

Meteorological Conditions
Cumulus clouds

Response Variables
Radar - evaluated rainfall is compared for both floating targets and in the total target.

Tests used
Mann - Whitney - Wilcoxon, Squared Rank, Student-t, Optimal C(α), and Maximum Likelihood

Conclusion
Two effects of seeding and one covariate have been identified to a significant level. Both effects support the hypothesis that dynamic seeding promotes cloud growth and merger.

758
11/15-131-51-81
Simpson, Joanne, Jane C. Eden, and Anthony R. Olsen, Aug., 1975, "On the Design and Evaluation of Cumulus Modification Experiments", JAM, 14, pp 946-958.

Experimental Design
The experimental design, model use, and extensive measurements have been published in detail (Simpson et al., 1970, 1971; Simpson and Wiggert, 1969; Woodley, 1970; Woodley and Herndon, 1970).

Type of Seeding
Airborne Ag-I pyrotechnic flares - (100-1000g per cloud)

Meteorological Conditions
Single isolated cumuli over South Florida.

Response Variables
26 paired data sets of rainfall from isolated cumuli.

Statistical Techniques
Classical and Bayesian procedures in multivariate analysis are used.

Conclusion
In all tests, the seed-control rainfall difference was significant at better than 5%. A multiplicative seeding factor of 2-3 was estimated in several ways.

759
22-238-59-90
Smith, C. G., February, 1975, "Cumulus Clouds Induced by Man", Weather, 30, pp 55-57.

Well defined cumulus cloud apparently grew out of a column of smoke from stubble fire near Brackley, England on 22 August 1974. There is discussion of the synoptic system.

7510
17-131/142-51-78
Thompson, John R., Keith J. Brown, and Robert D. Elliott, Oct., 1975, "Santa Barbara Convective Band Seeding Test Program: Final Report", Naval Weapons Center Technical Publication 5804, Naval Weapons Center, China Lake, California.

Experimental Design

Tests to determine the effectiveness of seeding convective portions of winter storms passing over Santa Barbara County were conducted from a 1065-meter mountain ridge using a pyrotechnic flare during four winter seasons from 1967-1968 through 197-1971 (Phase I). Bands were randomly chosen for seeding. Full scale aerial seeding operations were used from 1971-1972 through 1973-1974 seasons. The seeding was randomized in 48-hour blocks.

Type of Seeding

Phase I - Ag I pyrotechnic flares
Phase II - Ag I - NH_4 I - acetone burner

Meteorological Conditions

Convective bands of winter storms.

Response Variables

The primary mode of evaluation was approximately 100 raingauges.

Statistical Techniques

Primarily the single ratio.

Conclusions

Seeding of convective bands is an efficient means of augmenting water supplies with increases on the order of 50% to 100% within seeded bands.

SECTION 2
ABSTRACTS OF THEORETICAL LITERATURE AND DISCUSSION OF EXPERIMENTS

1947
47A
Bannon, J. K., Aug., 1947, "Artificial Stimulation of Rain Formation", The Meteorological Magazine, 76, No. 902, p 169-174.

This is a description of Australian experiments, (Kraus & Squires) some discussion of heat exchanges, formation of rain, turbulence, and conditions favorable for the stimulation of clouds.

1953
53A
Lehmann, E. L. (1953)
"The power of rank tests"
AMS 24: 23-43
Part of the computations in this work were carried out in connection with a project on the evaluation of rain making. Simple nonparametric classes of alternatives are defined for various nonparametric hypotheses in such a way that the power of rank tests against these alternatives can be easily evaluated; these results are illustrated with some numerical examples. The conclusions presented here rely on a theorem due to Hoeffding to derive tests possessing various optimum properties. Such results are obtained for Wilcoxon's one- and two-sample tests and for the rank correlation test for independence.

1955
55A
Ludlam, F. H., (August 1955), "Artificial Snowfall from Mountain Clouds", Tellus, 7, p. 277-290.
First the rate of growth of a crystal formed in the cloud, and the likelihood of its settling upon the mountain, are considered. Then an estimate is made of the concentration of crystals corresponding to the greatest possible snowfall rate, and the practicability of producing this concentration is discussed. Estimates are made of the frequency of occasions in Jämtland (central Sweden) suitable for seeding operations, the amount of snow which they might provide during a whole winter, and the cost. Finally, the problem of assessing the efficiency is considered.

1956
56A
Chapman, Douglas G. (1956)
"Estimating the parameters of a truncated gamma distribution"
AMS 27: 498-506

Several examples are given employing the incomplete gamma or Type III distribution in fitting rainfall data. This paper gives a simple table to simplify solution of the maximum likelihood equations for estimation of the parameters in the case that the data are untruncated. A new procedure is introduced for estimating the parameters of a truncated gamma distribution, and the asymptotic covariance matrix of the estimates is determined. It is noted that this method is applicable to a number of other truncated distributions (doubly truncated gamma distribution; singly or doubly truncated normal distribution; beta distribution with known range, either truncated or not), and would also be useful in estimating the parameters of the normal curve where there are systematic gaps in the observations.

56B
Moran, P. A. P. (1956)
"A test of significance for an unidentifiable relation"
JRSS B 18: 61-64
It is not possible to fit a simple linear regression when both variables are subject to error, but it is possible to identify bounds for the position and slope of the linear relation. It is shown here how it is possible to test whether the observed data show a significant divergence from the hypothesis that the line corresponding to an unidentifiable linear relation passes through a specified point in the plane. This test is then applied to the relationship between the total precipitation, in the form of rain and snow, on a catchment area, and the total run-off in streams and rivers.

1957
57A
Blackwell, David; Hodges, J. L., Jr. (1957) "Design for the Control of Selection Bias" Biometrika 28: 449-460.
An example is given relating to weather modification experiments: from a sequence of storms the meteorologist selects 2n storms deemed suitable for seeding. Of these, n are seeded and the rainfalls they produce are compared with those produced by the other n storms. If the meteorologist can guess whether or not the storm will be seeded if he selects it, his selection may be biased; this is selection bias. This paper considers to what extent selection bias can be controlled through design of the experiment. The problem is formulated as a two-person game, and it is found that among all designs, the truncated binomial minimizes the maximum expected number of correct guesses; in this method the successive treatments are selected independently with probability ½ each until n treatments of one kind have occurred. For this design, the expected number of correct guesses is independent of the prediction method, and is

$$n + n \binom{2n}{n} / 2^{2n} \sim n + (n/\pi)^{\frac{1}{2}}.$$

With this design, the variance in the number of correct guesses depends on the meteorologist's prediction method. In particular, two prediction methods are considered: (1) convergent prediction - predicts that treatment which has up to that point occurred less often; (2) divergent prediction - predicts that treatment which has occurred more often. It is found that against the truncated binomial design, the variance is maximized (minimized) when the divergence (convergence) strategy is used. It is noted that if treatments are selected independently at random, selection bias disappears, but the treatment numbers can no longer be preassigned. Several such designs are considered. Finally, much of what is argued here generalizes to experiments involving more than two treatments.

57B

Neyman, J., (1957), "Randomized Cloud - Seeding Experiment", Science, 125, p. 61-63.

This paper discusses the proposed operation for what appeared to be the first randomized experiment conducted in the United States using ground generators of silver iodide.

It was felt that the practical question of effectiveness of commercial cloud seeding, with the use of ground generators, was likely to be settled. However the framework of the experiment would leave unanswered a host of important theoretical questions.

At a conference it was decided to make public the existing arrangements with the hope that individuals, agencies, and institutions might undertake additional programs.

Points Raised:

1) Two independent sets of observations of precipitation.
2) Radar observations
3) Freezing nuclei observations
4) Airflow considerations
5) Synoptic Analysis.

1959

59A

Neyman, Jerzy; Scott, Elizabeth L. (1959) "On Some Immediate Problems of Research in Weather Control" Presented at Conference on the Design and Conduct of Research Programs in Weather Modification, Big Meadows, Virginia.

The authors discuss Volume II of the Final Report of the Advisory Committee on Weather Control and find that it contains:

1. some evasiveness in statements of certain scholars indirectly connected with the Report;
2. Misrepresentations supporting the soundness of evaluations of commercial cloud seeding projects (the method of evaluation in question is the so-called historical regression method);

3. unwarranted definite conclusions that certain commercial cloud seeding projects significantly increased precipitation. These statements, indicating seeding as the cause of increase in rain are unwarranted because they are based on historical regression analysis and not on results of a randomized experiment; in particular, a shrewd weather forecaster might be able to select only the outstanding storms of each type for seeding purposes;
4. concealment of important facts;
5. manipulation of data.

59B
Schaefer, Vincent J. and John E. Dieterich (1959)
"The seeding of cumulus clouds by ground-based silver iodide generators"
Zeit. Angew. Math. Physik 10: 174-188
This paper describes the operation of the 1957 Project Skyfire program undertaken in Western Montana, Northern Idaho, Eastern Oregon and Washington, whose objective was directed toward determining the degree of lightning suppression which might be achieved through cloud seeding operations. No statistical techniques are mentioned, but it is concluded that it is quite feasible to introduce enough silver iodide into cumulus clouds to produce unnatural effects wherever the clouds were colder than $-4^{\circ}C$. It is speculated that the charge separation process which leads to lightning generation may be modified to the extent that the cloud-to-ground strikes are reduced.

1960
60A
Brownlee, K. A. (1960) "Statistical Evaluation of Cloud Seeding Operations"
JASA 55: 446-453.
Summary: in 1953 Congress established the Advisory Committee on Weather Control, one of its responsibilities being to determine whether the US should experiment with activities designed to control weather conditions. In its Final Report (1957), the Committee concluded on the basis of historical records that in mountainous areas the Committee's analysis is reviewed in this paper, and it is concluded that possible selectivity on the part of the seeding operator could produce fictitious results. In the reviewer's opinion the Committee's claim for the positive effects of commercial seeding must be regarded as unproved.

Assuming that the seeding technique has been selected and the experimental unit defined, previous analyses have been conducted so that as each unit occurs a randomized choice is made whether to seed or not to seed. The observations will then by Y_{ij} for the target and X_{ij} for the control, $i = \begin{cases} 1 \text{ for the unseeded units} \\ 2 \text{ for the seeded units} \end{cases}$
The index j refers to the sequence of units in each class. A natural statistical analysis is to compare $\bar{Y}_1$ with $\bar{Y}_2$, adjusting for covariance on the X_{ij}. This is equivalent to fitting straight lines to the two classes of data, testing for parallelism, and then testing for coincidence of the lines. A more sophisticated design has been proposed in which two areas are observed, and randomly one or the other is seeded, thus giving an analog to a cross-over design. At the time of the Committee's Final Report, such a design had not been used anywhere.

60B
Neyman, Jerzy and Elizabeth L. Scott (1960)
"Correction for bias introduced by a transformation of variables"
AMS 31: 643-655
The problem of "normalizing" transformations is considered; in particular, the authors obtain minimum variance unbiased estimates of experimental treatments expressed in the original units. It is assumed that the transformation used is "faultless;" i.e., the transformed variables follow exactly normal distributions. Four particular normalizing transformations are considered: square root, logarithmic, angular (arcsin square root) and hyperbolicsine. The results are applied to the regression analysis of a randomized cloud seeding experiments.

1961
61A
Neyman, Jerzy and Elizabeth L. Scott (1961)
"Further Comments on the 'Final Report of the Advisory Committee on Weather Control'"
JASA 56: 580-600.
Two main conclusions were reached in the Final Report: (1) commercial cloud seeding in mountainous areas produced 10-15% increase in precipitation (2) no seeding project meant to increase precipitation was found in which the indicated effect of cloud seeding was negative. This paper reinforces Brownlee's criticism of conclusion (1) by documenting some of Brownlee's statements and by bringing out additional arguments against the validity of the conclusion; in particular, evidence is introduced showing that the apparent 10-15% increase in precipitation is likely to be due to a combination of factors other than cloud seeding. Conclusion (2) is also questioned, and is found inconsistent with some of the Committee's own findings and with some other published results. It is indicated that in the study of the South Dakota rain making operations, a Bayes decision rule whether to seed or not, published in the Final Report as minimizing the risks, may well maximize these risks.

1963
63A
Ludlam, Frank H. (1963)
"Cloud seeding experiments"
Z. Angew, Math. Phys. 14: 544-548
The author presents results from several early cloud seeding experiments (Langmuir's perodic seeding experiment, an Australian experiment on an individual cloud, experiments in the seeding of convective clouds undertaken in Arizona). He suggests that the first decade of experiments in cloud seeding was disappointing, inconclusive and uninformative because they were designed without the benefit of a firm theory. It is claimed that the construction of such a theory depends upon improvement in understanding of the dynamics of clouds, as opposed to the physics of their particles.

63B
Schaefer, Vicnent J. (1963)
"Some problems concerning weather control"
Z. Angew, Math. Phys. 14: 523-528
The author presents some general results obtained in weather modification research, and calls for the development of an "engineering phase" of weather modification; this activity would deal with "the procedures, logistics and routine operational problems which are the steps necessary to implement a reliable large scale utilization of scientific knowledge."

63C
Simpson, R. H. and J. S. Malkus, (1963), "An Experiment in Hurricane Modification: Preliminary Results", Science, 142, pp 498.
Experimental Design
Two cloud seeding experiments were performed in hurricane Beulah on 23 and 24 August 1963 (Project Stormfury). The purpose was to test a hypothesis relating storm and cloud processes, to compare results with a similar seeding of hurricane Esther in 1961, and to develop a foundation for improved hurricane experiments.

Conclusions
On first qualitative inspection, the results of the Beulah seeding are consistent with the hypothesis upon which the experiments were based.

63D
Weickmann, Helmut K. (1963)
"A realistic appraisal of weather control"
Z. Angew., Math. Phys. 14: 528-543
The author gives an expository discussion of the tools available to weather modification researchers, without considering problems of logistics, and proceeds to consider projects which might be carried out under consideration of logistic limitations. In particular he discusses the methodology of dry-ice seeding, water seeding, carbon seeding, nuclear bombs, ion seedings, seeding with detergents and release of latent instability. The goals of weather modification are classified into several areas, including precipitation control, tornado and hailstorm control, lightning control, hurricane control, evaporation control and radiation budget control.

63E
Woodcock, A. H., D. C. Blanchard, and C. G. H. Booth, (March 1963), "Salt Induced Convection and Clouds", Journal of the Atmospheric Sciences, 20, p 159-169.
It is shown that the addition of 20 to 40 mg. of finely divided sea-salt particles per kg of air to the lower atmosphere in oceanic areas should result in sufficient heating to cause ascending motions and perhaps to cause cloud formation.

1967
67A
Battan, Louis J.; Kassander, A. Richard Jr. (1967) "Summary of Results of a Randomized Cloud Seeding Project in Arizona" Fifth Berkeley Symposium 5: 29-33.

During the summers of 1957 to 1960, a series of tests was conducted over the Santa Catalina Mountains. One of two succeeding pairs of days was seeded according to a suitable randomization procedure. Silver iodide seeding was carried out by means of an airborne generator, with the aircraft being flown at an altitude where the temperature was about -6°C along a line perpendicular to the wind at that altitude and located upwind of the mountain target. The seeding runs ranged from two to over four hours in duration, starting at 12:30 MST. Effects of seeding on rainfall were sought by examining a network of 29 recording rain gauges during the period 1:00 to 6:00 MST. Following a preliminary analysis (using the Wilcoxon signed rank test and the Mann-Whitney U test), the experimental program was changed and a new set of tests was begun. In particular, (1) the flight altitude was established at 1000 to 2000 feet below the cloud bases; (2) the number of rain gauges was increased to 35 and concentrated over a smaller area; (3) the criteria for selecting suitable days were made more restrictive in order to reduce the relative frequency of experimental days with zero rainfall. Analysis of the results indicated no support of the hypothesis that silver iodide seeding can increase precipitation at the ground.

67B
Beimer, J. (1967) "On the Design and Evaluation of Cloud Seeding Experiments Performed by Electricité de France" Fifth Berkeley Symposium 5: 35-54.

The author describes various experimental projects conducted in France by Electricité de France during the years 1954 to 1967. In particular, four experiments (Agnes, Truyere, Maine-Touraine-Beauce, Cere-Maronne) are surveyed, with a detailed description being given of the randomized experiment Cere-Maronne. The Cere-Maronne project was undertaken to correct various imperfections in the designs of the previous experiments; probably the most important change was the randomization of seeding, with precipitation from a nonseeded trial being used as a control. The statistical tests used to evaluate the results of these experiments were confined to the likelihood ratio test and the t-test for the comparison of the slopes of the two simple regression lines (one for target one for control). Various transformations were used on the data, including the square root, cube root and log transformations.

67C
Brier, Glenn W., Thomas H. Carpenter, and Dwight B. Kline (1967)
"Some problems in evaluating cloud seeding effects over extensive areas"
Proc. Fifth Berkeley Symposium 5: 209-221

AD-A032 729 FLORIDA STATE UNIV TALLAHASSEE DEPT OF STATISTICS F/G 4/2
BIBLIOGRAPHY OF STATISTICAL AND METEOROLOGICAL METHODOLOGY IN W--ETC(U)
SEP 76 M A HANSON, C L BACH, E A COOLEY N00014-76-C-0394
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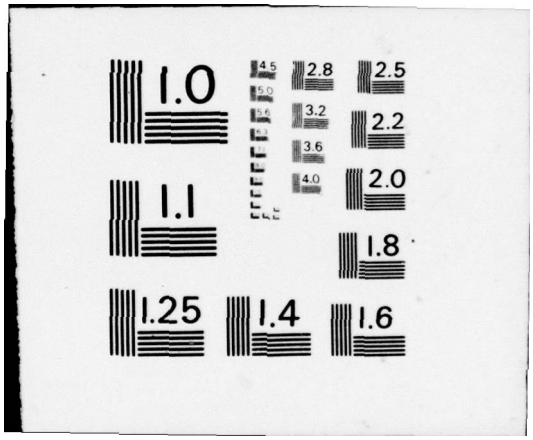
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This report gives preliminary results of an analysis performed on 16 operational cloud seeding programs in 11 project areas in eastern United States, involving a total of 62 seeded months. These were not randomized experiments, so no rigorous statement could be made regarding a causal relation between seeding and precipitation anomalies. The method of analysis included the following steps: make cube root transformation on all raw precipitation data, compute historical regression line for each station in the target and extended target areas for each project, evaluate residuals, etc. In addition, 41 unseeded months were chosen from periods in which no seeding took place, independently of the historical data from which the regressions were derived. Some tentative conclusions: (1) the seeded months are different from the historical months; (2) the seeded months are different from the unseeded months (chosen independently of the historical record); (3) the independent unseeded months show slight but not generally statistically significant anomalies in the negative direction, suggesting that if any bias exists in the statistical analysis, it tends to operate in a direction against finding positive effects of seeding. Suggestions are given for further analysis of the data.

67D
Changnon, S. A., Jr. and F. A. Huff (1967)
"The effect of natural rainfall variability in verification of rain modification experiments"
Proc. Fifth Berkeley Symp. 5: 177-198.

The authors describe a study in central and southern Illinois undertaken to determine the natural variability of rainfall in time and space. This paper concentrates on illustrating the magnitude of the variability in midwestern, warm season rainfall and the influence of this variability upon the interpretation of rain modification experiments. The data were classified into two categories consisting of (1) air mass or nonfrontal storms, and (2) all summer storms combined, and were used in a simulated seeding experiment to study the effects of different spatial and time units, classification by storm types and a comparison of different experimental designs. Also a limited study was undertaken to illustrate the possible influence of the gauge density factor (sampling errors, etc.). Several conclusions are drawn; in particular, estimates made in these studies indicated that sampling periods of five to ten years are inadequate to detect seeding effects of the order of 10 to 20 per cent when verification is based upon analyses of surface rainfall.

67E
Court, Arnold (1967)
"Randomized Cloud Seeding in The United States"
Fifth Berkeley Symposium 5: 237-251

The author covers some history of randomized experimental cloud seeding efforts in the United States, and it is concluded that no definitive experiment has yet been performed in the field. Some general observations are made: first, randomization has been the only concession to proper design in most experiments.

Randomization of itself does not guarantee, however, that a weather modification experiment is properly designed, and will give usable results. Suggestions are given as requirements for the statistical design of a proper experiment in weather modification. In particular, hypotheses concerning the principal result anticipated, as well as other significant consequences, must be formulated, and tests for them devised, and measurements for the tests planned and made.

67F
Davies, Robert B. and Prem S. Puri (1967)
"Some techniques of summary evaluations of several independent experiments"
Proc. Fifth Berkeley Symposium 5: 385-388

This paper is a contribution to the development of efficient statistical methods in weather modification experiments. Considered here are s independent experiments $E_1, E_2, \ldots, E_s$, each conducted to investigate the presence of certain effects. In particular, the i^{th} experiment is concerned with a parameter ξ_i which is a measure of a certain effect. Test statistics are given to test the following hypotheses:

$H_0: \xi_1 = \xi_2 = \ldots = \xi_s = 0$

$H_1: \xi_1 = \xi_2 = \ldots = \xi_s = \xi$, unspecified.

67G
Davis, L. G. and C. L. Hosler (1967)
"The Design, Execution, and Evaluation of a Weather Modification Experiment"
Fifth Berkeley Symposium 5: 253-269

The authors stress the importance of observations, models, and the understanding of natural events as prerequisites for meaningful modifications. Their plea is for detailed observational studies without randomization, and it is emphasized that the experimental design of seeding tests must be based on physical understanding. It is concluded that weather modification is not sufficiently advanced to expect that the job can be handled on the basis of small individual projects, and that future experimental avenues will have to be pursued on a much larger scale.

67H
Decker, Wayne L.; Paul T. Schickedanz (1967) "The Evaluation of Rainfall Records From a Five Year Cloud Seeding Experiment in Missouri" Fifth Berkeley Symposium 5: 55-63.

This paper describes Project Whitetop, a randomized experiment conducted from 1960 through 1964 in Missouri and Arkansas (summer only). The seeding was done from aircraft and was confined to a period beginning at noon and extending to 6:00 p.m. CST. Once suitable criteria for selection of days to be

included in the study were satisfied (based on amount of precipitable water and wind direction at 6:00 a.m.), a random selection of the seeded and non-seeded days was made. The plume area was defined (according to different criteria by the University of Chicago and University of Missouri - the Missouri plumes were smaller) to be the maximum region over which the seeding agent (silver iodide) could have spread. Various two-tailed hypothesis tests were conducted, (1) Missouri in-plume daily rainfall on seeded days vs. Missouri in-plume daily rainfall on nonseeded days, the t-test using logarithmic transformation gave highly significant results ($P < .01$), with seeded days having significantly less rainfall within the in-plume area then nonseeded days. (2) distribution of rainfall for Missouri in-plume seeded days vs. distribution for Missouri in-plume nonseeded days - the Mann-Whitney U test, excluding days with zero in-plume rain. (3) Missouri in-plume vs. Chicago out-plume: (a) t-test using log transformation - not significant at 5% level (b) t-test based on paired differences of in-plume and out-plume rain on each seeded day - not significant at 5% level.

671

Eberly, Donald L. and Lewis H. Robinson (1967) "Design and Evaluation of Randomization Wintertime Cloud Seeding at High Elevation" Fifth Berkeley Symposium 5: 65-90.

Silver iodide crystals were released from ground-based generators in a controlled test on the Lake Almanor watershed in California. This report describes the operation, outlines the details of the test, and describes the analysis of the data collected in 1963, the first year of the test. If southwinds predominate during the seeded period, the target area downwind from the generator group is seeded and a crossover test is used to evaluate the results of seeding. This involves comparing the precipitation in the seeded target area with the target area that was not seeded. The data obtained for the two targets is further subdivided into categories of cold and warm temperatures. If westwinds predominate during the seeded period and if the east burners are used, the target area is not seeded; if the west burners are operated, the target area is seeded. Thus, a target-control regression can be computed for the events where the target has been seeded and another regression computed for the periods when the target was not seeded. Again, the events are further subdivided into the two temperature categories. Factors likely to affect the response to seeding are identified: (1) variation of effect with temperature - warm and cold effects; (2) variation with time - the "Australian" effect (uniform decrease in seeding effect when individual successive events were analyzed); (3) variation with wind direction; (4) variation in space - gauge grouping to investigate cross contamination and distance maximum effects. Statistical methods employed include: (1) analysis of covariance; (2) regression analysis; (3) bivariate ANOVA; (4) Moran's common effect test; (5) ratio methods. No transformations of the data were made. An increase in precipitation was observed in the standard target area during seeding when the winds were from the west; no statistically significant result was detected from seeding clouds associated with southerly flow. Regression analysis was not performed in the southerly flow case, due to time limitations and unpromising prior results.

67J
Gabriel, K. R. (1967) "The Israeli Artificial Rainfall Stimulation Experiment. Statistical Evaluation for the Period 1961-65" Fifth Berkeley Symposium 5: 91-113.

A randomized cloud seeding experiment was carried out by silver iodide seeding from an aircraft in a crossover design. The experiment was based on comparison of amounts of precipitation in two areas, the North and the Center, separated by a buffer zone to avoid contamination of the atmosphere in one area when the other is being seeded. The amount of precipitation in each area was estimated by a simple average of daily precipitation recorded at different stations of the area. The experimental variable was defined as N-C, the difference between the two area averages. Days were classified as "dry" and excluded from analysis if there was no precipitation in the buffer zone. Various statistical methods were used to analyze the results of the experiment, including pairwise comparisons of North seeded days with Center seeded days using the Wilcoxon-Mann-Whitney test (also used to provide confidence bounds for the estimate of the percentage increase in precipitation due to seeding). Also investigated were variations in effectiveness of cloud seeding, seasonal differences, monthly differences, differences according to amounts of natural rainfall, differences according to the difference between rainfall in the buffer zone and the South, and differences according to cloud temperatures.

67K
Grant, Lewis O. and Paul W. Mielke, Jr. (1967)
"A Randomized Cloud Seeding Experiment at Climax, Colorado, 1960-65"
Fifth Berkeley Symposium 5: 115-131

The authors deal with the experimental design and statistical analyses used in the detection of changes in precipitation. Silver iodide was released from ground-based generators on the upwind mountain slopes of the Central Colorado Rockies. Unrestricted randomization was employed in obtaining the seeded and non-seeded samples, with the experimental time unit being 24 hours.

Two approaches are used to evaluate possible differences in precipitation due to seeding. The first approach is based on a parametric technique, under the assumption that precipitation data follows a gamma distribution. The second approach involves application of nonparametric procedures; in particular, two techniques are considered: (1) Wilcoxon rank-sum test, corrected for ties, (2) technique due to Mood.

A preliminary analysis of the data is summarized, with the following points made: (1) For the average of two representative target area stations and for the mean of the control stations, during the early part of the experiment, the seeded cases in the target area received much more precipitation than the nonseeded cases; this difference dropped rapidly starting at about 100 cases, then generally leveled off with a slight advantage for the seeded cases. The rapid drop occurred during an interval when control day concentrations of ice nuclei were high. (2) The experimental days were divided into three categories, placed according to the coldest 500 mb temperatures: (a) $-24^{\circ}C$ or less, (b) $-20^{\circ}C$ or warmer, (c) $-21^{\circ}C$ to $-23^{\circ}C$. For category (a), less precipitation occurred in the seeded cases than in the nonseeded cases, while for category (b), much more precipitation resulted on the seeded days.

Note: the analysis had not yet progressed to the stage of being able to give probability levels for these differences.

67L
Henderson, Thomas J. (1967)
"Tracking Silver Iodide Nuclei Under Orographic Influence"
Fifth Berkeley Symposium 5: 199-207

The author presents results from observational studies to establish the areal distribution of silver iodide downwind from ground generator sites and certain aircraft seeding flights. A few general conclusions are reached: (1) silver iodide freezing nuclei plumes are reasonably easy to track; (2) freezing nuclei plumes rarely conform to specific patterns and their dimensions in both time and space are difficult to predict; (3) it would be risky to make assumptions about the distribution of silver iodide plumes if a field program were dependent upon the material reaching a given area at a particular time and in a particular concentration.

67M
James, Barry R. (1967)
"On Pitman efficiency of some tests of scale for the gamma distribution"
Proc. Fifth Berkeley Symposium 5: 389-393

Let X represent the amount of rainfall during a day of nonzero precipitation under natural weather conditions, and Y the rainfall in the same region during a day of rain in which the clouds have been seeded. It is assumed that X has a gamma distribution and that the effect of seeding is multiplicative by some factor $\xi > 0$. The problem is to test, using samples $X_1, \ldots, X_m; Y_1, \ldots, Y_n$, the hypothesis

$H: \xi \geq 1$ vs. $K: \xi < 1$.

Several two-sample rank tests for scale change are considered (Wilcoxon, gamma scores, exponential scores, L test), and it is found that the exponential scores test offers greater Pitman efficiency than other nonparametric tests commonly used in weather control problems when the shape parameter is small (as in the cloud seeding experiment).

67N
Kahan, Archie M. (1967)
"The Bureau of Reclamation's Atmospheric Water Resources Research Program"
Proc. Fifth Berkeley Symposium 5: 271-282.

The author describes the conceptual basis, the recognized requirements, and the current and planned contract activities for the research program of the Bureau of Reclamation, aimed at ascertaining whether it is economically feasible to increase the water supply available to the reservoirs of the western states through the application of weather modification techniques. The program places emphasis on solving the problems of detection, measurement and evaluation of effects produced by cloud seeding. Attention is also paid to those problems of influencing the precipitation process which relate to the design of operational procedures.

67O
Müller, Hans Gerhard (1967)
"Weather modification experiments in Bavaria"
Proc. Fifth Berkeley Symposium 5: 223-235

The author presents some results of an experiment using silver iodide released from rockets, as well as from ground generators, to obtain more information about possibilities of suppressing hail by seeding hail clouds. It was not possible to employ randomization in this experiment, since the rocket and ground generator posts were manned on a voluntary basis. Some general conclusions are reached: (1) an eight-year period is far from providing significant data about a weather phenomenon as infrequent as hail; (2) the target area was too small compared with the variability of the weather situation; (3) more information about the experiment may be expected from a thorough examination of each special weather situation.

67P
Neiburger, M. (1967)
"Physical factors in precipitation processes and their influence on the effectiveness of cloud seeding"
Proc. Fifth Berkeley Symp. Math. Stat. and Prob. 5: 1-27.

The author reviews the status of our knowledge of the process of precipitation formation, covering both theoretical aspects and empirical results from research studies in cloud physics. He points out that no one has yet established a coordinated theory which would lead to quantitative estimation of precipitation rates and hence to those factors which would provide maximum precipitation for a given distribution of temperature, humidity and vertical velocity. Until such a theory becomes avaiable, estimation of parameters and changes required to produce a desired effect must depend upon experimental evidence.

67Q
Neyman, Jerzy (1967) "Experimentation with weather control" JRSS, Series A Part 3: 285-310.

This paper is basically an historical sketch of weather control experimentation, in which Neyman expresses the need for a reorientation of purposes of experiments. There is discussion on 1. present status of research on weather control-primarily a discussion of the NAS-NRC Panel on Weather and Climate Modification 2. present state of research on rain stimulation 3. problems of statistical theory.

67R
Neyman, Jerzey and Elizabeth L. Scott (1967)
"Some Outstanding Problems Relating to Rain Modification"
Fifth Berkeley Symposium 5: 293-326

This paper deals with the meteorological and statistical aspects of the problem of rain modification by seeding, with conclusions presented based on an analysis of five American experiments (SCUD, Whitetop, two experiments in Arizona and ACN experiment in Washington-Oregon) and the Swiss experiment Grossversuch III. Two basic premises are presented: (1) there exist (at least) two sets of conditions, A and B, in which seeding has opposite effects (precipitation is increased under A, decreased under B); it is the mixing of these conditions that explains the different experimental results noted in the literature; (2) these sets of conditions are identifiable in terms of the usual meteorological parameters (pressure, wind velocity, etc.). The problem then becomes the identification or the definition of the conditions. Some preliminary observations are made: (1) seeding seems to increase rainfall when the winds aloft are strong but not when they are weak; (2) seeding during the early part of a rainy period, as well as during the late part, appears to decrease precipitation. Several statistical problems are discussed, and it is noted in particular that the use of efficient statistical procedures is important in the evaluation of weather modification expeirments, since the time required to accumulate a sizable number of observations is usually inordinately long.

67S
Neyman, Jerzy and Elizabeth L. Scott (1967)
"Planning an experiment with cloud seeding"
Proc. Fifth Berkeley Symposium 5: 327-350

This paper was intended as an appendix to another paper by Neyman and Scott, "Some Outstanding Problems Relating to Rain Modification," also appearing in the Proceedings. It stands on its own as a contribution to the goal of designing future weather modification experiments, and focuses attention on several important problems. In particular, both the meteorological and statistical aspects are considered. It is noted that the meteorological aspects of planning an experiment with cloud seeding depend upon past experience, upon what the experimenter is prepared to adopt as a working hypothesis and upon the questions one wishes to have answered by the experiment. Statistical problems considered here include the role of randomization in planning a proper experiment, the theoretical problems, and the number of experimental units required to attain a preassigned precision. Some numerical illustrations are given, based on data collected by project SCUD.

67T
Neyman, J. and Elizabeth L. Scott (1967)
"Note on the Weather Bureau ACN Project"
Proc. Fifth Berkeley Symposium 5: 351-356

This paper provides information on the Weather Bureau ACN Cloud Seeding Project relevant to the discussion in another paper by Neyman and Scott, "Some outstanding problems relating to rain modification, also appearing in the Proceedings. The project experimental area was in Washington and Oregon, with cloud seeding being done with dry ice dispensed from aircraft.

Three types of targets were considered, all representing those sections of the general experimental area where the seeding was expected to have the greatest effect. For each test case, the targets were adjusted after the completion of the experiment, in accordance with prevailing winds. All of the experimental area lying outside of the target constituted the control area. Six different evaluations of effectiveness of seeding were performed, based on anomalies (for each gauge in the given target, the difference between the estimated amount of natural test period rainfall and the actual rainfall recorded for the test period). Several comments are made, and some numerical results are presented.

67U
Neyman, Jerzy and Elizabeth L. Scott (1967)
"Note on techniques of evaluation of single rain stimulation experiments"
Proc. Fifth Berkeley Symposium 5: 371-384

It is first noted that all the techniques employed in the authors' treatment of rain stimulation experiments are asymptotic techniques. Three general assumptions are made: (1) to each experimental unit, whether seeded or not, there corresponds a possibly positive probability that the target precipitation will be zero and this probability may be affected by seeding; (2) given that the target precipitation is not zero, it has a conditional probability density, joint with any predictors available; (3) if seeding has an effect on the distribution of nonzero target precipitation, then this effect is multiplicative. Tests of three distinct hypotheses are considered:

H_1: seeding does not affect the probability of nonzero rain in the target;

H_2: seeding has no effect on the distribution of nonzero precipitation in the target;

H_3: seeding does not affect the target precipitation averaged per experimental unit.

Optimal C(α) criteria are given for testing H_1 and H_2. The criterion advanced for testing H_3 is a linear combination of the criteria for testing H_1 and H_2, so adjusted as to be sensitive to departures from H_3 but not to departures from H_1 and H_2, if these latter departures are jointly consistent with H_3.

67V
Schmidt, Paul (1967)
"On 'Grossversuch III,' A Randomized Hail Suppression Experiment in Switzerland"
Fifth Berkeley Symposium 5: 141-159

This paper is a final report of the design, execution and results from Grossversuch III, conducted from 1957 to 1963. Silver iodide smoke was released from ground-based generators from 7:30 a.m. to 9:30 p.m. on randomly selected test days during the summer months. The test area was divided into four sections; due to practical considerations, it was decided not to use a comparison area. It was found that seeding was effective in increasing the number of hail days (where if at least one station in a section reported hail, this day counted as a "hail day" for this section).

Evaluation of precipitation amounts presented more problems. Indeed, no satisfactory test could be found under the assumption that precipitation amounts follow a gamma distribution. It was found, however, that the seeding probably did not influence the number of days with precipitation. Several nonparametric tests were applied (Kolmogorov-Smirnov using all experimental days, Wilcoxon-Mann-Whitney), but these were not entirely satisfactory either. It was decdied to present conclusions based on a test due to Taha, which accounts for the belief that the effect of seeding increased with the amount of natural precipitation. The results indicate that seeding was not effective when there would not have been rain, but that it significantly increased preciptation on rainy days. Taking general weather situations into consideration, it was found that on days with passing cold fronts, daily precipitation amounts were more than 20% greater for days with seeding. The differences between days with and without seeding were not significant for the days with local thunder storms and for the days with more than one storm situation.

Note: The computer programs used to evaluate the rain and hail results are available (written in FORTRAN 54 (IV)).

67W
Simpson, Joanne, (March 1967), "An Experimental Approach to Cumulus Clouds and Hurricanes", Weather, 22, No. 3, p 95-114.

This article is an explanation and summary of the work by the Atmospheric Physics and Chemistry Laboratory of ESSA (Environmental Science Services Administration) in conducting an experimental program focused on convective clouds and their role in larger-scale circulations.

Topics covered include hurricane studies, cumulus studies, prediction of seedability, and some case studies.

The overall conclusions were that the experimental approach should be capable of resolving some of the controversy about cloud seeding and should be able to make seeding and other techniques more powerful tools in understanding, predicting, and modifying cloud behavior.

Four color cloud photographs are included along with seventeen references.

67X
Siliceo, E. Pérez (1967)
"A Brief Description of an Experiment on Artificial Stimulation of Rain in the Necaxa Watershed, Mexico"
Fifth Berkeley Symposium 5: 133-140

Since 1949 silver iodide cloud seeding experiments were conducted in Necaxa. This report extends the evaluation given in earlier descriptions of the project. In order to investigate possible carryover effects of seeding, the first day after seeding is also studied. The target area was divided into two sections, the upper and the lower. The seeding was done by plane until 1955, with no seeding done in 1952. Beginning in 1955, ground-based generators were used. Seeding was done during the rainy season, and, starting with 1956, the days to be seeded were chosen at random at the beginning of the year.

Two methods of evaluation were used: (1) Historical regression - using seasonal data for the 15 years prior to the years of operation, a regression line was computed comparing rain in the Necaxa areas with that in the control zone. The deviations from the regression line in the historical years were taken to be due to natural phonomena. When the data for the years of operation are added, compared to the same historical regression line, the deviations should increase systematically if the seeding was effective. This method indicated that the effect of seeding was positive. Some decreases appeared, possibly due to torrential rains during cyclones, which affected the control zone more than the target areas. In the lower target the gains did not start until the use of ground-based generators. (2) Separation of daily precipitation amounts at the target into those for seeded days and those for unseeded days - days in which there were rains of more than 20 mm in the control zone were excluded. Daily departures from the normal amounts of rain in the upper target area of Necaxa (obtained from the 15 years of historical data) compared to those of the control zone were used to construct several histograms. The comparison showed a persistent increase until 1961, which deteriorated in the later years and even showed slightly negative values.

The analysis (no details here) of the unseeded day following each seeding period indicated an effect for more than one day, although less than two days, from the rain stimulation.

67Y
Smith, E. J. (1967)
"Cloud Seeding Experiments in Australia"
Fifth Berkeley Symposium 5: 161-176

This paper describes experiments in which silver iodide smoke was released from aircraft, giving suggestions for improvement in the experimental design. In particular, the following topics are discussed: (1) Past experiments on single clouds; (2) Past area experiments of two types: in the Snowy Mountains, two areas were used as target and control, and the decision whether clouds over the target area should be seeded as target and control, and the decision whether clouds over the target area should be seeded was randomized; in South Australia, New England and the Warragamba Catchment, clouds over one or the other of two areas were seeded, randomization determining which of the two was used as the target during any period. Note: full details and raw data are contained in annual reports issued by the Radiophysics Division of the Commonwealth Scientific and Industrial Research

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Organization in Sydney. (3) Suggestions for improvement to deal with the following problems: (a) Persistent effects of seeding: operate in alternate years; use unseeded control areas; use long periods of time and methods of analysis which are affected as little as possible by progressive changes in the ratio of rainfall in the target and control areas. (b) Variability of results of seeding: again, operate in alternate years; stratify results; carefully choose the clouds to be seeded, so that if a maximum increase in rainfall is desired, no seeding should take place in circumstances thought likely to lead to reductions in rainfall. (c) Experimental sensitivity limited by variations in rainfall gradients: provide two control areas, one on each side of the target area, which can be used to measure the rainfall gradient across the region. A new series of experiments was started in which clouds were seeded over areas and the above suggestions were taken into account; the first of these was conducted in Tasmania.

67Z
Wells, J. M. and M. A. Wells (1967)
"Note on Project SCUD"
Proc. Fifth Berkeley Symposium 5: 357-369

Project SCUD originated as an attempt to discover effects of cloud seeding on cyclones developing in the east coastal region of the United States. Seeding was done with silver iodide released from ground-based generators and with dry ice dispensed from aircraft. Two meteorological variables were observed, precipitation and pressure change, but this paper is concerned with precipitation only. There were two large fixed test regions and one smaller region adjustable to weather conditions. The main part of the paper deals with the reevaluation of the SCUD data. Two phases of reevaluation were considered: (1) use of the optimal $C(\alpha)$ criterion, which is asymptotically optimal with regard to the alternative that with nonzero precipitation the effect of seeding is multiplicative; (2) obtaining a point estimate of the multiplicativity factor.

67AA
Yates, Frank (1967)
"Discussion of reports on cloud seeding experiments"
Proc. Fifth Berkeley Symposium 5: 395-397

The author discusses the relationship of weather modification experiments to other areas of statistical application, and presents thoughts on some ideas which might be adapted and refined to be useful in cloud seeding evaluations. For example, the following suggestions are made: (1) Given concomitant observations on various physical and meteorological phenomena the results should be examined to see whether they influence the results; (2) (a) All experiments now completed or being conducted should be examined for long-term effects, and the evidence assembled as a whole so it can be critically appraised; (b) Future experiments should be so designed that they will provide direct evidence on long-term effects. Also, some thoughts on methods of estimation of seeding effects are given.

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67AB
Yerdjevich, Vujica M. (1967)
"Evaluation of Weather Modification as Expressed in Streamflow Response"
Proc. Fifth Berkeley Symposium 5: 283-292

The author presents an hypothesis that the pooling of both precipitation and streamflow response information into a unique statistical evaluation technique will provide more precise and quicker answers on the effects of cloud seeding than will precipitation data alone. Very little evidence is given to support such a claim. Some current methods of evaluating weather modification effects (target and control basin, randomization of time series, past records as control) are discussed.

67AC
"A collection of observational data" (1967)
Proc. Fifth Berkeley Symposium 5: 399-451

An introduction to this note calls for the establishment of a special institution whose purpose would be to serve as a source of information on all the major publicly financed experiments already completed and those in progress: what has been or is being observed, and what data are available and where. That same institution might also establish the routine of collecting photocopies of at least some observations as they are made, of organizing the data, preserving them and of making them available at cost. The main body of this note is a collection of raw data from five major cloud seeding experiments conducted in five different countries (Arizona experiments, an Australian experiment; an experiment in France, 1963-1964; Israeli experiment, 1961-1965; Swiss hail prevention experiment "Grossversuch III," 1957-1963). In all cases, rainfall data are accompanied by some collateral obserations; in some cases, there is information as to other data that is available and accessible.

1968
68A
Bowen, E. G., 1968, "Review of Current Australian Cloud-Seeding Activities", Proceedings of the First National Conference on Weather Modification, April 28 - May, 1968, Albany, New York, pp 1-7.

The effects of persistence in cloud-seeding experiments and the practical operations in progress as of 1968 are discussed. An experiment on the effect of persistence of cloud seeding is summarized.

Randomized seeding was used for a ten to fourteen day period. The whole experiment was switched on and off over a period of approximately twelve months. Comparison was made with adjacent control regions which were never seeded. The experiment was still in progress.

68B
Duran, Benjamin S; Mielke, Paul W. Jr. (1968) "Robustness of Sum of Squared Ranks Test" JASA 63: 338-344.

Many meteorologists participating in weather modification programs seem to feel that if a modification in precipitation takes place, it is essentially a scale change. Since precipitation distributions are asymmetric and one-sided, any exact mathematical description of any specific precipitation distribution is not known. Nevertheless, many individuals feel that the gamma distribution is at least a crude approximation to the actual distribution.

Taha introduced the sum of squared ranks test and showed it was superior to the Wilcoxon test for scale alternatives given a gamma distribution whose shape parameter is less than 11. Mielke obtained the exact first two moments of the sum of squared ranks test statistic when tied observations are present. This test like the Wilcoxon test has the advantage of being easy to work with computationally, but we can speculate that an exponent other than 1 or 2 will yield an even more powerful test for a given situation. There is doubt that the actual gain in power could be of much consequence in most applied situations. In addition to the problem of establishing simple criteria for the choice of exponent to use in a particular application, such tests would be computationally unpleasant.

The purpose here is to show that the unmodified sum of squared ranks test is a reasonable test to use when compared to the locally most powerful rank test for a number of specific asymmetrical distributions which have total mass confined to the positive axis. In particular, the asymptotic relative efficiency of this test to best tests for gamma distributions is maximized when the gamma distribution shape parameter is between 5 and 6.

68C
Kulkarni, S. R. (1968) "On the Optimal Asymptotic Tests for the Effects of Cloud Seeding on Rainfall: (I) The Case of Fixed Effects" Australian J. Stat. 10: 105-115.

Summary: Consider a sequence of experimental units which are to be treated according to some random scheme. A general randomized design is suggested for the purpose. Asymptotic tests, optimal in some sense, are derived for testing the hypothesis of the absence of seeding effect. Based on the asymptotic power of the tests obtained, optimality of various designs is discussed. Finally, an example is given to illustrate the results.

The design introduced in this paper generalizes the crossover and other designs, and Moran's result that the crossover design leads to an optimal test turns out to be a special case of the results presented here.

68D
Neyman, Jerzy; Elizabeth L. Scott; Marcella A. Wells (1968) "Influence of Atmospheric Stability Layers on the Effect of Ground-Based Cloud Seeding, I: Empirical Results" Proc. Nat. Acad. Sci. 60: 416-423.

This paper uses data from Grossversuch III to show that isothermal layers (stability layers) can complicate the mechanism of the effects of cloud seeding. The basic premise of rain stimulation with silver iodide seeding is the ice crystal nucleating property of the Ag I smoke at temperatures below -4°C. With ground-based generators, success depends upon the presence of updrafts capable of carrying the Ag I particles into the supercooled parts of the clouds before the Ag I is decomposed by photolysis. Ordinarily, temperature inversions and stability layers are obstacles to updrafts and are expected to prevent ground-based cloud seeding from being effective. For Grossversuch III, the target area was divided into four zones, and the 292 experimental days were categorized according to the intensity of obstacles to updrafts and according to the temperatures at which these obstacles occur. On days without stability layers, substantial increases in precipitation were expected due to seeding; no effects of seeding were expected on days with strong stability layers at temperatures above -4°C. It was found that days with uninhibited updrafts showed (nonsignificant) decreases in precipitation. Also, days with strong warm stability layers indicated increases in precipitation. Finally, in the combined category of days with stability layers it was found that in the mountainous zones rain increased substantially. Several questions are raised: (1) can the increase in rainfall by ground-based seeding in the presence of stability layers be confirmed in other experiments? (2) what is the mechanism of this phenomenon? (3) if the apparent decrease in rain on days with uninhibited updrafts is due to seeding, what is the mechanism of this effect?

1969
69A
Gabriel, K.R.; Paul Feder (February 1969)
"On the Distribution of Statistics Suitable for Evaluating Rainfall Stimulation Experiments"
Technometrics 11: 149-160. Feb. 1969

Summary: Two randomization tests of the null hypothesis in cloud seeding experiments are compared - the Wilcoxon-Mann-Whitney test and a test based on an average ratio of seeded to non-seeded amounts of precipitation. Data from the Israeli experiment (crossover design with daily random allocation of seeding to either the North or the Center of Israel suggest that the latter test is relatively more sensitive to apparent effects of seeding. The significance level of this test may be estimated by Monte Carlo methods or approximated by using the asymptotic normal distribution of the average ratio. Sampling trials show that this approximation is adequate only when the experiment is of several years' duration.

Comparison: R has advantage of depending directly on amounts of seeded vs. unseeded rainfall, whereas U depends on these amounts only indirectly. The WMW test will be quite insensitive to effects of seeding varying a great deal from day to day, but the R statistic will show them clearly. The WMW technique is merely a test of significance and does not provide a quantitative estimate of the size of seeding effects. To obtain estimates and confidence bounds one must have recourse to rather cumbersome techniques whose results lean heavily on one's assumptions regarding the form (e.g., additive, multiplicative, etc.) of the effects.

69B
Kulkarni, S. R. (1969)
"On the Optimal Asymptotic Tests for the Effects of Cloud Seeding on Rainfall (2) The Case of Variable Effects"
Austral. J. Statist. 11: 39-51

The author extends his earlier results to the case where the effects of cloud seeding are assumed random. A new formulation is given of the problem of testing the variable effects of a treatment with reference to a general randomized design, and the locally asymptotically most powerful tests are obtained. The crossover design and the randomized design with non-controlled predictor variables turn out as special cases. The theory is illustrated by an example using data from a cloud seeding experiment conducted in Quebec, 1959-1963 (cross-over design).

69C
Lovasich, Jeanne L.; Jerzy Neyman, Elizabeth L. Scott, Jerome A. Smith (1969) "Timing of the Apparent Effects of Cloud Seeding" Science 165: 892-893.

The average hourly precipitation amounts, on 96 experimental days without cloud seeding in the Whitetop experiment, show a marked maximum between 4 and 7 p.m., presumably reflecting the convection activity caused by heating of the ground occurring during an earlier period. No such maximum is observed on the 102 days with seeding. The only mechanism of a decrease in the rainfall, apparently induced by seeding, is that of "overseeding". Ordinarily it is discounted as a practical impossibility. An alternative hypothesis, due to J. Hughes, depends upon the presumption that the dispersal of silver iodide smoke causes widespread cloudiness. If this is so, then the ground temperatures at midday and early afternoon on days with seeding are likely to be lower than on days without seeding, with the consequent difference in the cumuli formation in the late afternoon. This hypothesis requires confirmation, possibly through cloud-chamber experiments and certainly through the analysis of observations in the free atmosphere. The hypothesis does tend to explain certain findings relating to the Swiss experiment Grossversuch III.

Notes: 1. The only statistical method mentioned is "the two-tailed test"; more specific information is not given.
2. In a later paper (A) the authors found that (a) the noted differences in precipitation on seeded and not-seeded days occurred not only after the commencement of seeding but also during several hours before seeding; (b) they could not verify Hughes' hypothesis.

69D
Neyman, Jerzy (1969)
"Statistical Problems in Science. The Symmetric Test of a Composite Hypothesis"
JASA 64: 1154-1171

The author discusses an interaction between probability and statistical theory, on the one hand, and research in science, on the other. Research in science invariably involves some observations x, indicating that no mathematical treatment of the problem is possible without the assumption that x is a sample value of a random variable X.

Neyman uses the Swiss hail prevention experiment Grossversuch III as an example of an observational situation in which an assumption of randomness of the state of nature appears too artificial to adopt. In this type of situation there will be a sequence of conclusions or decisions about the relevant states of nature.

69E
Neyman, Jerzy (1969) "Science and Politics of Rainmaking: A rejoinder" Bull. of the Atomic Scientists 15: No. 3, 27.

Neyman defends his position presented before the Royal Statistical Society concerning the report of the NAS-NRC Panel on Weather and Climate Modification. He maintains that it is deplorable that the material in the Panels report was published under the aegis of the National Academy of Sciences.

69F
Neyman, Jerzy; Elizabeth Scott; Jerome A. Smith (1969) "Areal Spread of the Effect of Cloud Seeding at the Whitetop experiment" Science 163: 1445-1449.

This study is motivated by the continuing discussion of whether cloud-seeding technology is advanced sufficiently to justify federal expenditures on large-scale cloud-seeding operations, contemplated as a means of alleviating water shortage, etc. An analysis of the Whitetop experiment was performed, using statistical methods based on optimal $C(\alpha)$ tests. The authors reach several conclusions: (i)two large cloud-seeding experiments, Grossversuch III and Whitetop, indicate strongly not only that cloud seeding can affect rain, but also that its effect can spread over very large areas; (ii)the conditions in which increases or decreases due to seeding occur are largely unknown; hence it is questionable whether sufficiently advanced weather modification technology exists; (iii)the benefits to humanity from the identification of these conditions would be enormous, hence further research is needed; (iv)the most important need in such research is the accumulation of well documented facts which can be obtained only through large, properly designed, and carefully conducted randomized experiments (eg., Battan's work in Arizona, Grossversuch III, Whitetop). Note: past experiments have been conducted with the cross over design, involving seeding on every experimental day over one of two alternative targets, selected at random. The distances between the alternative targets range from almost zero to about 40 miles. From the point of view of the effects that seeding may have at distances of some 150 miles, the data of such experiments are useless.

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69G
Neyman, J., E. L. Scott and M. A. Wells (1969)
"Statistics in Meteorology"
Review of the International Statistical Institute 37: 119-148

The first part of this paper is expository in nature, and deals with such topics as the history of attempts to modify weather, the variability of the distribution of rainfall, and the need for new developments in experimental design and in statistical inference.
The second part of the paper is devoted to the discussion of several aspects of statistical problems encountered in weather modification experiments. In particular, two major experiments (Whitetop and Grossversuch III) were analysed to evaluate the spread of the effects of seeding. Both experiments used crossover designs, and it was found that the effects of seeding spread to distances in excess of 100 miles. It is concluded that adoption of the crossover design in a new experiment could be hazardous.

69H
Stigler, Stephen M. (1969) "The use of random allocation for the control of selection bias" Biometrika 56: 553-560.

This paper considers the problem of selection bias presented by Blackwell and Hodges. A slightly different model is considered here; rather than necessarily biasing the experiment by an amount Δ on each trial, it is only assumed that the meteorologist picks a subject with expected response between $\mu - \Delta$ and $\mu + \Delta$. Thus he may choose not to bias the experiment at all, picking a subject with expected response μ. The truncated binomial design is still minimax in this new model. It is desired to obtain a design having small risk when the meteorologist uses strategy θ_1, yet has a maximum risk only slightly higher than that of the truncated binomial; θ_1 is given as follows: if the meteorologist observes that in the first i of the 2n trials, exactly j A treatments and i-j B treatments have been assigned, then on the $(i+1)^{st}$ trial he picks a subject with expected response

$$\mu + 2\Delta\left(\frac{n-j}{2n-i} - \frac{1}{2}\right),$$

thus biasing by an amount proportional to the fraction of treatments yet to be assigned which must be A's. It is found that the above requirements are met by the random allocation design, where the statistician picks n of the first 2n integers at random without replacement, and gives treatment A to the subjects corresponding to the integers selected. It is also shown that random allocation is a restricted Bayes design within the class of Markov designs.

1970
70A
Lovasich, Jeanne L.; Neyman, Jerzy; Scott, Elizabeth L.; Smith, Jerome A. (1970) "Statistical aspects of rain stimulation - problems and prospects" Rev. of the International Statistical Inst. 38(1): 155-170.

The authors express their conviction that, because an informative experiment with cloud seeding must last for some 5 to 10 years, progress in the study of weather modification depends on the analysis, both statistical and meteorological, of experiments already completed, so that hypotheses suggested by one experiment could be verified on others. In particular, the analysis of two cloud seeding experiments (Grossversuch III and Whitetop) indicated that cloud seeding can cause both large increases (Grossversuch III) and large decreases (Whitetop) in precipitation, both over unexpectedly large areas. In both cases at least some of the effects noted are not those anticipated.
The authors call for the organization of an international interdisciplinary study group, charges with the responsibility of bringing out a volume containing reliable and verifiable factual information on all the weather modification experiments conducted in all countries willing to cooperate. This group should be composed of several national subgroups working independently but having access to the same data.

70B
Moran, P.A.P. (1970)
"The methodology of rain-making experiments"
Review of the International Statistical Institute 38: 105-119

The author discusses experiments designed to test (and allow for estimation of) the increase in average rainfall over an area due to seeding. He considers past attempts to analyse weather modification data, and offers suggestions for improved mthods. In particular he presents problems associated with using a gamma distribution to approximate observed rainfall distributions and criticizes the historical regression method employed by some researchers. It is finally suggested that since previous long-term experiments have not given clear results, it might be better, in the short run, to seed clouds only when the effects of seeding are immediately visible; the author acknowledges that this could be a difficult task, but argues that it would at least provide short term answers.

A discussion follows the main text of the paper, with comments by M. Schüepp, Lyle D. Calvin, W. A. O' N. Waugh, A. C. Atkinson and A. M. Walker, and a reply by the author.

70C
Schickedanz, Paul T. and Gary F. Krause, Feb., 1970, "A Test for the Scale Parameters of Two Gamma Distributions using the Generalized Likelihood Ratio", *Journal of Applied Meteorology*, 9, p 13-16.

This paper develops a test between the scale parameters of two gamma distributions with common shape and compares its power with that obtained by applying the t test to non-transformed and transformed data.

An example is given for weekly rainfall data. The power of the tests are computed and compared.

Conclusion

The likelihood ratio test for differences in gamma-scale parameters is more powerful than the t test applied to log-normal means. Since many meteorological variables are known to be gamma distributed, this test should have several applications in meteorology.

1971
71A
Dennis, A. S., R. A. Schleusener, Alexander Koscielski, and M. R. Schock, (1971), "Modification of Precipitation from Convective Clouds in the Northern Plains of the United States", Proceedings of the International Conference on Weather Modification, Sept. 6-11, Canberra, Australia, pp. 103-110.

This paper gives a summary of principal field projects under Project Skywater, 1966-1970.

Also included are observations of seeding effects on shower clouds, silver iodide seeding of large convective clouds and salt seeding of large convective clouds.

71B
Lovasich, J. L.; Neyman, J.; Scott, E. L.; Wells, M. A. (1971) "Hypothetical Explanations of the Negative Apparent Effects of Cloud Seeding in the Whitetops Experiments." Proc. Nat. Acad. Sci. USA 68: 2643-2646.

In order to explain the apparent losses of rain ascribable to seeding at the Whitetop trial, three hypotheses have been suggested:
(i) Battan suggested that because no mechanism is known whereby seeding could produce effects in the upwind areas, the noted apparent losses of rain in the Whitetop experiment could not have been caused by seeding.
(ii) Tribus and Braham and Flueck hypothesized that the deficiencies of rain on seeded days were due to overseeding.
(iii) Hughes hypothesized that seeding causes widespread cloudiness and subsequent lowering of ground temperatures.
This paper is an attempt to verify hypothesis (iii). The results are in the negative: the cloudiness-temperature hypothesis is flatly contradicted by the data: the seeded E-days (but not W-days) were uniformly less cloudy and hotter than those without seeding (E and W referring to wind directions). These differences prevailed not only from the scheduled time of seeding but also for several hours beforehand. This and other disparities suggest the possibility that the noted deficiencies of rain on seeded days are due to some problems of effective randomization, a possibility which is confirmed by additional analysis. Hence any conclusions about the effectiveness of seeding, one way or the other, that are based on the Whitetop experiment must be made with extreme caution.

71C
Moran, P. A. P.; (June 1971), "The effects of serial correlation on a randomized rain-making experiment", Preprints, Int-Symp. on Prob. and Stat. in the Atmospheric Sciences, Honolulu, Hawaii, 129-130.

Experimental Design
2n experimental units with n selected at random for seeding; also considers paired units with randomized seeding.

Statistical Techniques

This is a paper on statistical methodology. Says standard analysis is two-sample student test for first design. Is concerned with serial correlation; takes $\rho_{ij} = \rho^{|i-j|}$, $-1<\rho<1$. Assumes multivariate normal for 2n observations with equal variances σ^2. Considers what happens to t when correlation is present. Concludes that the null distribution of t is still correct (well known) but proves is enhanced for positive ρ which should be expected.

Similar conclusions are given for the second design with the paired sample t.

Conclusions

Paper is simply concerned with the effects of serial correlation on t-tests in two designs. It is noted that the assumptions of normality are suspect but that it is the simplest case to consider.

71D

Neyman, Jerzy; Osborn, Herbert B. (1971) "Evidence of Widespread Effects of Cloud Seeding at Two Arizona Experiments" Proceedings of the National Academy of Sciences 68: 649-652.

This paper undertakes to obtain answers to two questions with regard to two consecutive experiments in Arizona: (i) does silver iodide seeding show significant effects, positive or negative, on precipitation in areas far removed from the intended target? (ii) if yes, are such effects limited to periods of time when the particular areas were downwind from the source of seeding material, or are they also noticeable upwind? Significance probabilities were calculated. Results: 1. large significant apparent effects of seeding were found at substantial distances from sites of seeding. 2. these apparent effects were losses in rain. 3. the significant apparent effects were limited to downwind days. Paper suggests that the lack of significant apparent effects in the original evaluations of the Arizona experiments may be due to the brief time over which the rainfall used for evaluation was measured.

71E

Schickendanz, Paul T., and Huff, Floyd A., (June 1971), 'The Design and Evaluation of Rainfall Modification Experiments', JAM, 10, pp. 502-514.

This is an evaluation of (i) the effect of stratifying the data on detection of seeding effects for a given design using highly accurate measurements, (ii) the various rain parameters as a means of detecting seeding effects for a given design, and (iii) the efficiency of various statistical designs.

Results were based on measurements by 49 raingauges arranged in a nearly uniform grid pattern in a 400 square mile flat area in Illinois. The effects of a variety of statistical designs were considered.

Discussion of optimal data, test, design and data type is given. Recommendations are made for design and evaluative procedures.

71F
Simpson, Joanne and Victor Wiggert, Feb., (1971), "1968 Florida Cumulus Seeding Experiments: Numerical Model Results", Monthly Weather Review, 99, p. 87-118.

A one-dimensional numerical cumulus model was tested against data from a randomized seeding experiment made in South Florida in 1968. Fourteen GO clouds were studied. Nine were seeded by pyrotechnics with 1 kg of silver iodide each, while five were studied identically as controls.

A high correlation was found between seedability and radar-measured rainfall increase from seeding. Also, a high correlation was found between model predictions of the difference in precipitation between seeded and control clouds and the measured rainfall differences.

The model prediction for each GO cloud is discussed in comparison with actual measurements on the cloud. The 1968 experiment was found to subdivide into two periods, one fair and one disturbed, with quite different effects of seeding. It is concluded that the disturbed period was less favorable for seeding because of higher unseeded cloud growth and strong wind shear. Implications for future modeling efforts are discussed.

1972
72A
Burke, E. and D. F. Kriege, (1972), "An Analysis of the Effects and Benefits of the Weather Modification Program in Santa Clara County", Third Conference on Weather Modification, June 26-29, Rapid City, S.D., pp 143-145.

The Santa Clara project ran from 1955-1969 and was a target-control type. The control stations were located along the Santa Cruz Mountains and the target stations were in the Santa Clara Valley and its watersheds. Silver iodide seeding was used.

A model is developed to provide a mechanism for performing a sensitivity analysis with respect to the various statistical parameters.

72B
Clark, R. S., P. St.-Amand, and T. L. Wright, (1972), "Modification of Warm Convective Clouds by Hygroscopic and Hydrophilic Materials", Third Conference on Weather Modification, June 26-29, Rapid City, S.D., pp. 179-181.

The life cycles of 40 untreated warm cumulus clouds are investigated and detailed. Also significant findings from both hygroscopic and hydrophilic seeding experiments are presented.

72C
Hannan, E. J. and P.A.P. Moran (1972)
"The effects of serial correlation on a randomized rain-making experiment"
Austral. J. Statist. 14: 256-261.

This paper deals with the problems of seasonal variation and serial correlation, which complicate the analysis of weather modification experiments. It is concluded that in the presence of positive serial correlation of the size ususally found in meteorological data, the power of tests which are known to be optimal in the absence of serial correlation is likely to be increased, while the distribution under the null hypothesis is likely to be fairly unaffected. The power can be further increased if the serial structure is understood; here a general discussion is given of suitable designs.

72D
Henderson, Thomas J. and William J. Carley, (1972), "The Airborne Seeding of Six Tornadoes", Third Conference on Weather Modification, June 26-29, Rapid City, S.D., p 241-244.

This is a description of seeding of two tornadoes in Kenya and four in Texas. These tornadoes occurred during hail suppression operations. Descriptions of two tornado seedings are given.

The point in these experiments to date is not that the tornado intensity decreased following seeding but rather that the tornado intensities have not increased following the seeding application.

72E
Neyman, Jerzy (1972) "Problems of design and of evaluation of rain making experiments" J. N. Srivastava, ed., A Survey of Statistical Design and Linear Models, 443-458.

The author stresses the multidimensional character of rain stimulation studies, and concludes that a fully satisfactory evaluation of a rain making experiment seems to require contours, computed for each hour after the inception of the seeding period, enclosing areas within which the estimated effect is significant. In particular, the evaluation must include:
(1) precipitation amounts in surrounding areas, downwind, upwind and to the sides;
(2) the time after the start of seeding at which its effects on rainfall began to be felt at stated distances and at stated directions. Note: the great variety of conditions in which rain stimulation is investigated falls into three broad categories: (i) area seeding of summer convective clouds, occasionally labeled "air mass" clouds, (ii) area seeding of winter storms, (iii) so-called dynamic seeding of particular clouds and of their systems. Neyman's work at Berkeley has been primarily concerned with category (1).

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72F
Neyman, Jerzy; Osborn, Herbert B.; Scott, Elizabeth L.; Wells, Marcella A. (1972) "Re-evaluation of the Arizona Cloud-Seeding Experiment" Proceedings of the National Academy of Sciences 69: No. 6, 1348-1352.

This is a sequel to an earlier paper primarily concerned with the broad question whether "local" cloud seeding with silver iodide, intended to augment the rainfall over a limited area, can in fact affect the precipitation at relatively large distances. The general pattern of this study parallels that of the earlier paper. Note: earlier, in similar discussions, the authors used to quote apparent widespread effects of seeding found for the Whitetop experiment. But a more recent study showed that the noted significant difference in precipitation on seeded and not-seeded days occurred not only after the commencement of seeding but also during several hours before seeding.

72G
Neyman, Jerzy and Scott, Elizabeth L. (September 1972), "Asymptotically Optimal Tests of Composite Hypotheses for Randomized Experiments with Noncontrolled Predictor Variables." JASA 60, 699-721.

Basic assumptions are presented regarding the distributions of observable variables and the possible effect of the treatment under study. This is done with particular reference to unrestricted randomization of the experiment. The authors summarize the results of an earlier investigation on which the present developments are based. This includes the definition and the construction of locally asymptotically optimal tests. The general theory is applied to the deduction of the locally asymptotically optimal test corresponding to the unrestricted randomization of the experiment.

72H
Osborn, Herbert B., (1972), "Comments by a Hydrologic Engineer on Cloud Seeding in Arizona", Third Conference on Weather Modification, June 26-29, Rapid City, S.D., p 146-151.

Descriptions of two Arizona cloud seeding experiments are given:

1) Santa Catalina Experiment - from 1957 to 1964 two successive cloud seeding experiments were carried out over the Mountains of southern Arizona using Ag I seeded upwind, and the precipitation was measured by a network of gauges.
2) A 4-week program of seeding cumulus clouds was carried out to increase summer rainfall in eastern and central Arizona during 1971. A rough estimate gave a 15% increase.

The remainder of the article deals with questions raised by thunderstorm cloud seeding and criteria needed for such investigations.

72I
Kenick, J. H., A. J. Chisholm, and P. W. Summers, (1972), "The Seedability of Multicell and Supercell Hailstorms Using Droppable Pyrotechnic Flares", Third Conference on Weather Modification, June 26-29, Rapid City, S.D., pp 272-278.

This paper discusses an airborne droppable pyrotechnic flare cloud seeding system. Specific analysis include multicell storms and supercell storms.

Examples of seeding of multicell and supercell storms are given with descriptions and analysis of flares and their effects.

Conclusions on how multicell and supercell storms should be seeded are given.

72J
Williams, M. C., W. F. Rowland, and J. N. Srivastava, (1972), "On the Choice of an Experimental Unit and a Block System for Weather Modification Experiments", Third Conference on Weather Modification, June 26-29, Rapid City, S.D., p 321-324.

The purpose of this paper is twofold. One is to describe an investigation of the effectiveness of unrestricted randomization. The second is to develop a system of blocks such that restricted randomization within blocks may provide an increase in information of the order of 25% to 30%.

The conclusion drawn from the analysis is that unrestricted randomization would need to be modified.

This modification consists of stratifying the unit by storm type, essentially forming a "system of blocks".

Results

An analysis of variance shows that under the block randomization method approximately 3/4 as many observations would be needed as under the unrestricted randomization method.

72K
Wu, Sing-Chou; Williams, James S.; Mielke, Paul W. Jr. (December 1972), "Some Designs and Analyses for Temporally Independent Experiments Involving Correlated Bivariate Responses." Biometrics 28, 1043-1061.

Summary - designs and analyses are derived for experiments with two experimental units where responses are correlated within and independent among time periods. Fisher's information function for the treatment parameter is maximized to obtain most informative designs for estimating a treatment effect. In the absence of pre-test or historical data on the two units, the most informative design is always a blanced crossover (crossover

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arrangement where each of the two units is treated equally often). With historical data, the design is either a continued covariate (only one unit is treated throughout the test period - inferences are made conditionally on a linear combination of responses which over time has a constant expected value), or an augmented crossover (intermediate cases where the covariance analyses cannot be applied). Efficient analyses of continued covariate and balanced crossover designs are shown to be examples of maximum likelihood estimation and the analysis of covariance. For the augmented crossover designs, maximum likelihood methods and Wilks' lambda criterion are used to provide efficient large sample procedures. It is shown that use of a most informative design and efficient analysis instead of more familiar designs and analyses can result in a sizable decrease in the variance of the treatment effect estimator.

1973
73A
Neyman, Jerzy; Elizabeth L. Scott; Marcella A. Wells (1973) "Downwind and Upwind Effects in the Arizona Cloud-Seeding Experiment" Proc. Nat. Acad. Sci. USA 70: 357-360.

This study is concerned with the apparent effects of seeding in the Arizona experiment on the 24-hr. rainfall measured by all the available raingauges located within 180 miles of the intended target, the Santa Catalina Mountains. The authors also describe the "moving grid method" of defining groups of gauges used in evaluating the effects upwind, downwind, and to the sides. The purpose of the moving grid studies was to obtain information as to possible effects of cloud seeding over the target on rainfall in far-away localities to which the prevailing winds could carry the silver iodide smoke released over the target or, at least, the masses of air into which this smoke was introduced while they were over the target. The authors conclude that cloud seeding in the Arizona experiment did indeed decrease the rainfall in those areas that were far downwind. Hence it is seen that the frequently-used cross-over design of the experiment is unreliable. Also, because the amount of silver iodide smoke at a distance of some 100 miles from its source must be minute, the mechanism governing the effects of Ag I seeding cannot be limited to nucleation of supercooled droplets. It is speculated that as the Arizona experiment was performed, the seeding may have initiated rain high above the ground, while when falling through dry air, evaporated and decreased the temperature, and while carried downwind the parcel of cool air eventually reached the ground and inhibited convection.

73B
Neyman, Jerzy; Scott, Elizabeth L. (1973) "Rain Stimulation Experiments: Design and Evaluation" Proceedings of the WMO/IAMAP Scientific Conference on Weather Modification, WMO no. 399: 449-457.

The authors emphasize five main points:
1. the necessity of randomizing cloud seeding experiments, because of the variability of natural rainfall from one unit of observation to the next and because of the changes in rainfall regimes each lasting several years.

2. the need for the understanding of atmospheric phenomena of great complexity, the verification of theory being accomplished empirically only through randomized experiments.

3. the effects of cloud seeding observed empirically are occasionally positive (Grossve such III), occasionally negative (Arizona experiments) and occasionally no change, and are extensive in both time and place. These results indicate that experimental designs based on area-to-area comparisons (eg., cross-over design) are unreliable.

4. with reference to summer convective clouds, several interrelated but independently conceived mechanisms of post-cloud-seeding phenomena have been suggested.

5. Experiments with rain stimulation are multidimensional, involving such questions as (a) how far does the effect of cloud seeding extend? and (b) When does the effect of cloud seeding begin and when does it end? At this point in time, no statistical theory applicable to such questions exist.

1974

74A

Brier, Glenn W. (1974) "Design and evaluation of weather modification experiments" Weather and Climate Modification, ed. Wilmot N. Hess

This paper gives a brief description of some of the techniques of design and evaluation of weather modification experiments, and describes the concepts upon which these techniques are based. In particular, the author discusses three typical designs:

1. Target-only design-involves a single area (or cloud) - used in commercial rainmaking operations and in preliminary or exploratory work - not likely to be very sensitive in detecting small or moderate seeding effects.

2. Target-control design-involves a single area that is seeded on a randomized basis and a nearby control area that is never seeded, and (presumably) not affected by the seeding - often better than the target-only design, but problems of contamination may arise: (a) spread of seeding material into the control area, (b) spread of effects of seeding material beyond the intended target through "dynamic contamination".

3. Crossover design-involves two areas, only one of which is seeded at a time, with the area for seeding selected randomly for each time period again, problems of contamination may arise also, there may be a "persistence effect" (effect of seeding in an area after the seeding has been terminated.

Author also discusses various methods of analysis, including t-tests, C(α) tests, nonparametric (sign, signed rank, Wilcoxon-Mann-Whitney, squared rank) tests and use of transformations and covariates. Finally, he gives proposals for future research.

74B

Brier, Glenn W., (1974), "Weather Modification Experiments Design and Evaluation", Fourth Conference on Weather Modification, November 18-21, Fort Lauderdale, Fla., p 290-292.

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In the area of experimental design, often serious questions about the effectiveness of some of the classical designs such as cross over and target-control are raised. This is because of the possiblity of contamination of the control area, either directly or indirectly, from the treatment of the target area. Furthermore, evidence is accumulating for the existence of effects extending beyond the nominal target (or control) area.

Methods of data analysis include multiple regression procedures, graphical analysis, and use of partitioning, i.e., post hoc stratification.

Tests such as the t-test, optimal C(α), likelihood ratio tests and non-parametric are used. Bayesian inference is discussed.

Summary

First, we must document the physics of the natural clouds and rainfall so that we undertake a physically sound experiment and so that an optimal selection of statistical tools can be made.

Second, judicious use of several types of statistical tools must be incorporated at all stages from design through evaluation.

Thirdly, cloud physics and/or model simulation should be introduced as early as possible.

74C
Brier, Glenn W., Lewis O. Grant, and Paul W. Mielke, Jr., 1974, "The Evidence for Extra-Area Effects From Purposeful Weather Modification Projects", Fourth Conference on Weather Modification, November 18-21, Fort Lauderdale, Fla., p 510-515.

This paper presents a brief review of a number of projects that have been investigated for extended area effects and attempts to interpret the results leading to some conclusions and recommendations for further investigation of the problem.

Programs

Winter: Commercial East Coast, Climax I-II, Park Range, Santa Barbara II, and Israel.
Summer: Commercial East Coast, Arizona I-II, Grossversuch III (Swiss Alps) and Whitetop (Missouri).

Conclusions

1) The basic design of future weather modification experiments should include provisions for evaluation and testing of extra-area effects
2) Instrumentation should provide for adequate monitoring of physical processes and effects outside as well as inside the target area
3) Modeling and theoretical studies should be intensified and extended
4) Studies of economic and social benefits and costs should be expanded to include extra-area effects.

74D
Byers, Horace R. (1974) "History of Weather Modification" Weather and Climate Modification, ed. Wilmot N. Hess: chapter 1.

This paper is an historical survey of weather modification, emphasizing the 20-year period from 1947 to 1967. The author discusses, among other topics: (1) The Santa Barbara Project - a commercial project aimed at increasing the water supply which was derived from rains and snows in the mountains north and northeast of the city - one of the principal cloud seeding programs evaluated by the California State Water Resources Board, which assigned the statistical evaluation to Neyman and his workers at the Statistical Laboratory at Berkeley - probably the only cloud seeding contract in which the clients permitted randomization. (2) The Australian Experiments - results of doubtful significance were obtained using the target-control crossover design. (3) Arizona Experiments (1957-1960 and 1961-1964) - none of the various analyses of the data supported the hypothesis that airborne silver iodide seeding increased rainfall or influenced its areal extent over the mountain range where the convective clouds formed. (4) Israeli Experiments - randomized crossover design, involving airborne silver iodide seeding of cumulus clouds. (5) Grossversuch III - intended as a randomized experiment in hail suppression, using ground-based generators - analysis revealed that the frequency of hail was greater on seeded than on unseeded days, but the average rainfall was 21% higher than on unseeded days. (6) Report of the National Academy of Sciences (1966) - the author concludes that the members of the panel wanted to express optimism concerning the future of wather modification, but hedged their statements in order to preserve their self-respect.

74E
Calvin, L., J. Flueck (ed.), F. Mielke, J. Pezier, P. Schickedanz, J. Simpson, M. Tribus, and H. Weickmann, 1974, "Quantitative Methodology in Weather Modification: A Panel Discussion on Design and Evaluation", Fourth Conference on Weather Modification, November 18-21, Fort Lauderdale, Fla., p 344-346.

This paper is directed towards acquainting the weather modification community with the different statistical methodologies available.

Topics Discussed

1) The Classical Statistical Viewpoint
2) The Statistical Decision Theory Viewpoint
3) The Data Analysis Viewpoint
4) The Cumulus Cloud Modelling and Experimentation Viewpoint
5) The Meso-Climatology Viewpoint
6) The Physics and Laboratory Research Viewpoint.

74F
Carley, William J. 1974, "The Impact of Storm Conditions on Cloud-Seeding in the NIRE", Fourth Conference on Weather Modification, November 18-21, Fort Lauderdale, Fla., p 108-113.

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This paper presents three studies of how conceptual models almost never adequately reflect the actual case.

First is the fact that the classical model of the isolated severe thunderstorm is not the only source of damaging hail.

Secondly, preconceptions of storm behavior either in general or on the basis of local information are likely to be inappropriate.

Thirdly, and perhaps most importantly, is the fact that an operational decision and adjustment in the operational approach within a period of five minutes or less may mean the difference between staying ahead of the system or falling behind.

74G
Changnon, Stanley A., Griffith M. Morgan, Jr.,Gary L. Achtenerier, Neil G. Towery, and Ronald C. Grosh, 1974, "Design of a Hail Suppression Project for Illinois", Fourth Conference on Weather Modification, November 18-21, Fort Lauderdale, Fla., p 293-300.

Design of an Experiment to Suppress Hail, DESH, began in 1973, with the 3-year goal of developing an optimum design of a hail suppression experiment in Illinois.

The studies of DESH include investiagtions of:

1) social aspects of an experiment
2) background silver in hail and rain for ecological concerns
3) hail forecasting techniques for operational and evaluation utility
4) seeding systems to select best suited midwestern hailstorms
5) radar to monitor operations and evaluations
6) unwanted side effects
7) characteristics of midwestern hail producing clouds
8) modeling of single and multiple convective clouds for evaluation and understanding.

74H
Chary, Henry A., 1974, "Problems and Progress in Ground-Based Cold Fog Dissipation", Fourth Conference on Weather Modification, November 18-21, Fort Lauderdale, Fla., pp 279-281.

This paper discussed the United States Air Force development and operational use of a ground-based cold fog dissipation system.

The main problems are:

1) Nozzle icing
2) Terrain effects
3) The influences of air pollution

Summary

The icing problem can be solved by nozzle design, the use of anti-icing agents, sheltering, etc.

Terrain effects can be at least partially overcome by local low level wind flow studies and by using tall dispenser masts.

The problem of pollution has no immediate solution at the present time.

74I
Elliott, Robert D. (1974) "Experience of the Private Sector" Weather and Climate Modification, ed. Wilmot N. Hess: chapter 2.

The author is President of North American Weather Consutants at the Santa Barbara Municipal Airport, and he presents here an historical survey of weather modification from the practitioner's point of view. He discusses, among other topics: (1) Colorado State University's Climax field experiment (1960-1965) - Mielke and Grant found that seeding from the mountain slope with a silver iodide - sodium iodide complex at the rate of 20g/hr did not overseed until the cloud top was colder than -23°C, in Santa Barbara County (1967-1970) field tests carried out by the author's company indicated similar results, although the clouds and mode of seeding were different. (2) Whitetop project - Neyman, Scott, and Smith, in a study which extended up to 200 miles downwind, found a net decrease in precipitation; the reality of this was contested by Schichedanz and Huff. (3) First Santa Barbara project (1957-1960) - involved an effort by the author's company, the State of California, and the Statistical Laboratory at Berkeley. The results were provocative, there being overall considerably more precipitation in the seeded cases. The statistical significance of the results remained in doubt, however, partly as a result of the inclusion of Ventura County into the project after its commencement. It was realized that physical measurements other then rainfall were required to fully evaluate a project.

74J
Gagin, A.; Neymann, J. (1974) "Rain Stimulation and Cloud Physics in Israel" Weather and Climate Modification, ed. Wilmot N. Hess: chapter 13.

This paper gives a summary of Israeli weather modification experiments and their results, including sections on Israel's water potential and cloud physics aspects of the experiments of particular interest is the discussion of the statistical aspects of the 1961-1967 project. A crossover design was used by Gabriel (16), who used the root-double-ratio statistic

$$R = \left(\frac{N_s}{C_u} \cdot \frac{C_s}{N_u} \right)^{\frac{1}{2}},$$

where s refers to days seeded (days allocated randomly to seeding irrespective of whether the day was actually seeded or not), u to days unseeded. N and C stand for the average rainfall of the two areas (N and C are the initial of the two areas, North and Center, of the 1961-1967 experiment). Gabriel and Feder showed that R is asymptotically normal as the number of rain days increases, although some criticism of their paper was put forward by a referee of the paper by Neumann and Shimbursky. Several points are made concerning the use of the crossover design: (1) together with the test statistic R, the crossover design eliminates, to some extent, the effects of the natural fluctuations in rainfall; (2) the design avoids the direct use of historical rain data; (3) with the crossover design it is desirable for the rainfalls of the two experiment areas to be highly correlated. This often means that the two areas are to be situated near one another, leading to the possibility of "cross-contamination".

74K
Gentry, R. Cecil and Staff, 1974, "The Experimental Hurricane Modification Program", Fourth Conference on Weather Modification, November 18-21, Fort Lauderdale, Fla., pp 95-96.

The following items should be considered in the evaluation of hypotheses.

1) Determine whether the storm is suitable for modification
2) Determine whether the hurricane is in a hostile environment.
3) Measure parameters that will indicate that modification has taken place in accordance with the hypothesis.
4) Study the natural variability of the tropical cyclones.
5) Study the response of different scales of motion to the seeding process using the variational optimization approach.
6) Randomize time of initiating the seeding rather than randomize selection of experimental storms.

74L
Grant, Lewis O.; Kahan, Archie M. (1974) "Weather Modification for Augmenting Orographic Precipitation" Weather and Climate Modification, ed. Wilmot N. Hess: chapter 7.

This paper reviews the Rocky Mountain snowpack enhancement (Climax) experiments (1960-1965 and 1965-1970), including sections on (1) the nature of orographic clouds, (2) the physical basis for seeding orographic clouds, (3) the technology for seeding "cold" orographic clouds. Of particular interest is the discussion of results of field experiments. Several findings are presented: (1) In both the Climax I and Climax II experiments, the actual amount of precipitation on seeded days corresponds closely to the amount of cloud condensate available for the production of precipitation. This is clearly not the case for nonseeded days for warmer cloud temperatures. (2) It is shown that seeding potential depends on the rate at which condensate becomes avaiable in the orographic cloud. This is presented in terms of the wind velocity near cloud base at Climax. The importance of wind direction is also noted. (3) The total change in observed

precipitation is primarily controlled by a change in the duration of precipitation events, rather than by a change in intensity during times of natural precipitation. One of the difficulties in evaluating weather modification efforts is that programs that have showed significant results are likely to have been those that experienced cloud characteristics that provided a preponderance of events in the categories favoring increases or decreases in precipitation. The Climax experiments provided for meteorological stratification to test for differences in precipitation for groupings of events expected to have a similar response to seeding.

74M

Gray, Wm. N., Wm. N. Frank, M. L. Corrin, and C. A. Stokes, 1974, "Weather Modification by Carbon Dust Absorption of Solar Energy", Fourth Conference on Weather Modification, November 18-21, Fort Lauderdale, Fla., pp 190-209.

It is hypothesized that significant beneficial influences can be derived through judicious exploitation of solar absorption potential of carbon black dust.

For example it may be used for enhancement of precipitation over land areas to alter extra-tropical cyclones, and to speed up fog burnoof and snowmelt.

This paper discusses the physical hypothesis from the meteorological, radiational, engineering, ecological and economic points of view.

Conclusions

Carbon dust directly warms the atmosphere and much larger energy accumulations are possible. It appears that greater potential economic benefit may be derived from this.

It is suggested that meso-scale atmospheric response might be enhanced if the carbon dust was used to create or stimulate a meso-scale cumulus convective system and silver iodide seeding was then employed to further enlarge the already existing cumulus elements.

74N

Hitschfeld, W. F., 1974, "Hail Suppression: Evaluation and Other Problems", Fourth Conference on Weather Modification, November 18-21, Fort Lauderdale, Fla., pp 97-98.

Two studies are discussed:

1) In 1972, the Alberta Hail Studies (ALHAS) eschewed a statistical seeding experiment. Analysis of records was sophisticated rather than powerful.
2) The National Hail Research Experiment (NHRE) (1972-1976) was a statistical randomization experiment. However P. I. Schickedanz and S. A. Changnon calculated that they would need 47 years of experiments if the seeding was only 20% effective.

The author suggests that a combined approach need not be only "physical/statistical" but could contain a combination of statistical analyses of two or more kinds of parameters.

740
Hobbs, Peter V., 1974, "Artificial Modification of Orographic Clouds and Precipitation Over the Cascade Mountains", Fourth Conference on Weather Modification, November 18-21, Fort Lauderdale, Fla., p 414-419.

A brief description of three aspects of the Cascade Project are given:

1) The development of theoretical models to simulate the flow of air over mountain ranges, the formation of clouds, and the growth and fallout of precipitation.
2) A comprehensive study of the micro structure of the winter clouds and the nature of the precipitation which they produce.
3) A series of detailed physical case studies of the effects of artificial seeding on the clouds and on the distribution of snowfall across the Cascade Range.

Conclusions

If the results of the statistical evaluation confirm those obtained through physical evaluation, an operational cloud seeding program could be initiated with well defined expectations.

74P
Lovell, Clifton C., 1974, "The Statistical Design in the NHRE", Fourth Conference on Weather Modification, November 18-21, Fort Lauderdale, Fla., pp 99-102.

A randomized target design, sometimes referred to as a single area design and sample seeded and unseeded events in roughly equal proportions were chosen. The experimental unit began at 1000 hours and ended at dark. A criterion of radar reflectivity was used to declare Hail Days. Difficulties of thunderstorms in northeast Colorado are discussed.

74Q
Mielke, Paul W., Jr. (February 1974)
"Squared Rank Test Appropriate to Weather Modification Cross-Over Design"
Technometrics 16: 13-16.

Summary: The sum of squared ranks test is applicable to an experimental design in which treatments (such as seeding or not seeding clouds with Ag I) are randomly applied to a specific target vicinity.
An alternative experimental design for evaluating weather modification effects involves randomly seeding one or the other of two adjacent target areas. This RBD has been designated as a cross-over design and, assuming contamination between target areas is of little consequence, this design has definite advantages over the previously mentioned design.

Joint evaluation of the two target areas associated with a cross-over design is inappropriate with the sum of squared ranks test. A squared rank test appropriate to the cross-over design is presented. The exact conditional variance under the null hypothesis of the associated test statistics in the case of existing tied observations is presented. The distribution for which the squared rank test is asymptotically optimum against location alternatives is given and compared with analogous distributions associated with the Wilcoxon and median tests. The intuitive reason for using squared ranks in preference to linear ranks is to emphasize those experimental units (in this case specific units of time) associated with the largest treatment effects.

A specific numberical example is given.

74R

Mueller, Eugene A. and Stanley A. Changnon, Jr., 1974, "Comparison of Echo Statistics for Seeded and Non-Seeded Storms in NHRE 1973", Fourth Conference on Weather Modification, November 18-21, Fort Lauderdale, Fla., p 114-118.

This paper describes methods evaluating radar reflectivity data.

The evaluation presents two classical approaches. One is a comparison of the reflectivity frequencies for the seed and no-seed days in the target and the second is a comparison of the reflectivities found in two fictional control areas.

The results show a major difference between reflectivities, primarily those above the freezing level, on seeded and no-seed days.

74S

Mueller, H. G., M. E. Reinhardt, H. Willeke, and F. Katheder, 1974, "Dissipation of Supercooled Fog in Upper Bavaria", Fourth Conference on Weather Modification, November 18-21, Fort Lauderdale, Fla., p 286-289.

This paper discusses the dissipation of supercooled fog using a ground based source of liquid CO_2. All equipment was mounted on a truck so as to modify supercooled fog in a special target area. Visual and photographic observations were made.

Results

It was shown that supercooled fog up to at least 400m thickness can be dissipated with good efficiency using liquid carbon dioxide on a mobile unit.

74T

Olsen, Anthony R., (1974), "Development and Comparison of Bayesian and Classical Statistical Mehtods as Applied to Randomized Weather Modification Experiments", Fourth Conference on Weather Modification, November 18-21, Fort Lauderdale, Fla., p 319-322.

Bayesian and classical procedures are presented using the same assumptions concerning the form of the rainfall distributions, the use of a multiplicative effect and selected cases of known parameters. The parallel development of the two methodologies was done to emphasize that inference procedures for both can be found and that the difficulties in applying either are comparable. No attempt was made to choose one over the other. Moreover, in the case of the Bayesian analysis no discussion of the selection of an appropriate prior distribution was attempted.

74U
Olsen, Anthony R., (1974), "On the Effect of Natural Rainfall Variability and Measurement Errors in the Detection of Seeding Effects", Fourth Conference on Weather Modification, November 18-21, Fort Lauderdale, Fla., p 323-328.

This research was done in the context of the Florida Area Cumulus Experiment (FACE), FACE is a randomization by day experiment.

The major thrust of this study was embodied in a computer simulation of area cloud seeding experiments using field measurements as input. Measurement errors were introduced.

Statistical Techniques

1) Likelihood ratio test of two gamma distributions
2) Optimal C(α) test
3) Two-sample squared rank tests
4) Wilcoxon-Mann-Whitney test
5) Two-sample t-test using fourth root transformed data
6) Two-sample t-test using log transformed data

Conclusions

It appears that gauges in the appropriate density or a gauge adjusted radar will provide measurements of acceptable accuracy.

The most serious obstacle to the detection of a seeding effect is natural rain variability. Therefore, it is critical that some criteria be followed (physical model or predictors) to reduce this variability.

Due to large variability, the most efficient statistical tests, (the likelihood ratio and optimal C(α)) should be used.

74V
Simpson, Joanne and Jane C. Eden, 1974, "On the Design and Evaluation of Cumulus Modification Experiments", Fourth Conference on Weather Modification, November 18-21, Fort Lauderdale, Fla., p 312-318.

This paper is a study of the problems encountered and the progress made in evaluation of the Experimental Meteorology Laboratory's (EML) randomized single cumulus project over southern Florida.

Statistical Techniques

Monte Carlo simulation, maximum likelihood, t(1/4 root), t(ln), Wilcoxon rank, squared rank, Bayesian.

Conclusions

The EML data set for randomized dynamic seeding of single cumuli has been examined in detail and a positive seeding effect has been established. (5% level of significance). The single cumulus experiment illustrates many of the pitfalls encountered in attempts to modify convective rainfall, such as "heavy-tailed" distributions and offers some insights concerning how these pitfalls can be avoided and/or overcome.

74W

Smith, E. J. (1974) "Cloud Seeding in Australia" Weather and Climate Modification, ed. Wilmot N. Hess: chapter 12.

This paper gives a summary of Australian weather modification experiments and their results, including sections on experiments with dry ice and silver iodide, a cloud seeding experiment in Tasmania (beginning in 1964), ongoing cloud physics research, and suggestions for future experiments. Of particular interest is the description of four experiments carried out during the period 1955 to 1963 in southeastern Australia. Probably the most puzzling result is that there seems to be a persistent effect of Ag I seeding, perhaps lasting into periods when no seeding was supposed to have occurred. It is possible that the effects may have gradually, over a long time, spread out from the target area. Rainfall during the experiments was more variable in amount than it had been before they started, and the variability of rainfall depended on the seeding even in areas where the mean rainfall was unaffected; (2) in Warragamba, there were increases in rainfall from cold clouds and decreases when warmer clouds were seeded; in contrast, the results of the New England experiment suggested a substantial increase in rainfall on days when cumulus clouds with tops colder than $-10^{\circ}C$ were seeded, but there appeared to be no change in rainfall on days when the seeded clouds were warmer.

74X

Weinstein, Alan I., (1974), "Air Pollution and Warm Fog Dispersal", Fourth Conference on Weather Modification, November 18-21, Fort Lauderdale, Fla., p 282-285.

This paper discussed how artificial condensation nuclei in concentrations observed near and downwind of pollution sources, could drastically reduce initial visibility and thus put a heavy load on some evaporative techniques for fog dispersal.

The practical limit of relative humidity suppression by hygroscopic particle seeding is approximately 2-3%. Using a model, it can be seen that at these small humidity depressions, the visibility in clean air fogs can be raised to greater than 800 meters, while that in polluted fogs is in the range of 200 to 800 meters depending upon the pollution severity.

Conclusions

With the increased data on air pollution levels operational warm fog dispersal may be feasible. Considerations of pollution should become part of the decision making process.

74Y

Woodley, William Lee and Anthony R. Olsen, 1974, "Optimizing the Measurements of Convective Rainfall in Florida", Fourth Conference on Weather Modification, November 18-21, Fort Lauderdale, Fla., p 307-311.

This paper weighs the relative merits of gauge and radar systems of convective rain measurement for the evaluation of an area seeding experiment, and suggests an optimal system that combines the best features of each. This was done concurrently with the randomized cloud seeding experiments in southern Florida.

Response Variables

A dense raingauge network and WSR-57 radar.

Statistical Techniques

Two-tailed t-test

Conclusions

The most acceptable position to take at present is that radar, when adjusted by gauges will do as well as the uniform gauge array spread over the entire target. Also the author believes there is reason to argue that radar will do better, but it is difficult to determine this improvement quantitatively.

1975

75A

Olsen, Anthony; Simpson, Joanne; Eden, Jane C. (May 1975)
"A Bayesian Analysis of a Multiplicative Treatment Effect in Weather Modification"
Technometrics 17: 161-166.

Summary: Bayesian techniques are developed to investigate a multiplicative treatment effect when data samples on a control and a treatment are available. The RV's (seeded and unseeded rain volume) are assumed to follow highly skewed gamma distributions with the same shape parameters. The data sample is from a randomized airborne pyrotechnic seeding experiment on 52 isolated cumulus clouds in South Fla. from 1968 to 1972; half of the clouds were massively injected with Ag I smoke and the other untreated half were identically observed. The physical hypothesis is that massive seeding can, under specified conditions, invigorate cloud growth and thereby cause increased precipitation.

The experiments were guided by a numerical simulation of cumulus growth which specified suitable conditions in terms of a "seedability" parameter (defined as the difference in predicted maximum height of seeded vs. unseeded clouds).

Once an experimental unit is determined to be eligible for the experiment, a randomized decision is made to determine if the unit is to be subjected to the treatment or left as a control. In either case, the appropriate set of observations are taken. Numerous other variables were measured to test parts of the physical hypothesis and the numberical simulation.

Parameter of interest is $\theta = \mu_t/\mu_c$ = factor by which the treatment multiplies the average response that would occur if the treatment had not been applied to the experimental unit.

INDEX OF EXPERIMENTAL PROCEDURES

(The first two digits refer to the year of publication.)

Experimental Design

Crossover design: 633, 661, 665, 671, 673, 674, 685, 686, 6810, 693, 694, 701, 713, 745, 746.

Factorial design: 6610.

Multiple cloud seeding: 521, 695, 7012, 7016, 718, 719, 7217, 732, 757, 7510.

Paired cloud seeding: 7014.

Pattern recognition: 642.

Periodic seeding: 502, 754, 755.

Random seeding of bands: 686, 691, 703, 714, 716, 726, 7216, 741, 752.

Single cloud seeding: 471, 491, 492, 501, 503, 523, 641, 662, 669, 675, 676, 687, 688, 704, 7017, 711, 717, 718, 723, 729, 7413, 758.

Two sample using control: 524, 525, 531, 581, 601, 611, 631, 632, 634, 651, 663, 664, 672, 684, 689, 6812, 692, 702, 706, 708, 7010, 7011, 7013, 7015, 712, 715, 7110, 721, 722, 724, 727, 728, 7210, 7211, 7212, 7213, 7214, 731, 733, 742, 743, 744, 748, 749, 7410, 7411, 7412, 7414, 751, 758.

Two sample using historical records: 504, 522, 541, 582, 666, 667, 705, 709, 7015, 725, 756.

Two sample using estimates from meterological parameters: 551, 552, 561.

Seeding Agent

Ammonium iodide: 726, 729, 732, 752, 7510.

Ammonium nitrate: 717.

Burning vegetation; urban heat: 6812, 7015, 7211, 747, 759.

Dry ice: 471, 491, 492, 501, 503, 504, 523, 531, 642, 666, 6610, 6811, 731, 754, 755.

Gasoline engines; industrial pollution: 688, 705, 7211.

Lead aerosols: 707.

Morpholine, ethylamine: 744.

Phloroglucinol: 631.

Portland cement: 748.

Silver iodide: 502, 504, 522, 523, 541, 561, 581, 601, 611, 632, 633, 634, 641, 651, 661, 662, 663, 664, 665, 666, 667, 669, 671, 673, 674, 675, 676, 681, 682, 683, 684, 685, 686, 687, 6810, 6811, 691, 692, 693, 694, 695, 701, 702, 703, 704, 706, 708, 709, 7010, 7011, 7012, 7013, 7014, 7016, 7017, 712, 713, 714, 715, 716, 718, 719, 7110, 721, 722, 724, 725, 726, 728, 729, 7210, 7212, 7213, 7214, 7215, 7216, 7217, 731, 732, 733, 741, 742, 743, 745, 749, 7410, 7411, 7412, 7413, 7414, 751, 752, 754, 755, 756, 757, 758, 7510.

Sodium cloride: 672, 689, 711, 746.

Sodium iodide: 662, 663, 702, 714, 728, 729, 7213, 751.

Urea: 668, 717, 723.

Water: 521, 523, 717, 7211.

Response Variables

Cloud texture: 6610.

General weather data: 502, 561, 611, 7211.

Hail indicators: 7010, 727.

Ice counters: 707, 7412.

Particle or drop collectors, spectrophotometers: 662, 687, 688, 705, 707, 7213, 7412.

Radar-cloud census: 671.

Radar-rainfall, hail, snow: 471, 492, 501, 522, 641, 642, 666, 669, 675, 684, 689, 6811, 695, 702, 704, 7012, 7014, 7016, 7017, 711, 718, 719, 723, 724, 728, 7213, 7214, 7215, 7216, 7217, 741, 742, 746, 748, 7410, 7413, 751, 754, 755, 757.

Radiosonde: 714.

Rain gauges: 522, 523, 524, 525, 541, 551, 552, 581, 601, 632, 633, 634, 651, 661, 663, 664, 665, 667, 672, 673, 674, 681, 682, 683, 684, 686, 689, 6810, 6812, 691, 692, 693, 694, 703, 706, 7011, 7013, 7015, 713, 714, 716, 7110, 721, 722, 724, 726, 728, 7212, 7213, 7214, 7216, 7217, 732, 733, 741, 742, 743, 745, 746, 749, 7411, 7413, 7414, 751, 752, 756, 758, 7510.

Snow measurements: 633, 708, 712, 731, 754, 755.

Stream flows, reservoir runoff: 531, 582, 666.

Visual, photographs, photogrammetry, crop damage: 471, 491, 492, 501, 503, 504, 521, 522, 523, 531, 631, 641, 668, 669, 675, 676, 695, 701, 704, 7014, 717, 723, 725, 729, 7210, 7215, 744, 747, 748, 759.

Statistical Techniques

AUTHOR INDEX

(The first two digits refer to the year of publication. Following numerical symbols refer to the experimental abstracts (Section 1); following alphabetical symbols refer to the theory and discussion abstracts (Section 2)).

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

1. REPORT NUMBER	2. GOVT. ACCESSION	3. RECIPIENT'S CATALOG NUMBER
ONR Technical Report No. 110		

4. TITLE (and subtitle)	5. TYPE OF REPORT & PERIOD COVERED
Bibliography of Statistical and Meteorology Methodology in Weather Modification	Technical Report
	6. PERFORMING ORG. REPORT NUMBER FSU Statistics Report M388

7. AUTHOR(S)	8. CONTRACT OR GRANT NUMBER(S)
Morgan A. Hanson Charles L. Bach Edward A. Cooley	Office of Naval Research Contract No. N00014-76-C-0394

9. PREFORMING ORGANIZATION NAME AND ADDRESS	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
Florida State University Department of Statistics Tallahassee, Florida 32306	

11. CONTROLLING OFFICE NAME AND ADDRESS	12. REPORT DATE
Office of Naval Research Statistics & Probability Program Arlington, Virginia 22217	September, 1976
	13. NUMBER OF PAGES 138

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	15. SECURITY CLASS (of this report) Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

REPORT DOCUMENTATION PAGE

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from report).

18. SUPPLEMENTARY NOTES

19. KEY WORDS

Bibliography, Weather Modification

20. ABSTRACT

BIBLIOGRAPHY OF STATISTICAL AND METEOROLOGY
METHODOLOGY IN WEATHER MODIFICATION

This is a comprehensive bibliography of weather modification literature.